

FINAL

**FEASIBILITY STUDY FOR
ZONE E, OPERABLE UNIT 12
LANDFILL 4**

F. E. Warren Air Force Base, Wyoming

Prepared for:

90 SW/EM

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List of Acronyms

AFCEE	Air Force Center for Environmental Excellence
AFI	Air Force Instruction
ARAR	Applicable or Relevant and appropriate requirement
BGS	below ground surface
BMPs	best management practices
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPC	chemicals of potential concern
COR	Contracting Officer's Representative
CY	cubic yard
DAF	dilution attenuation factor
DRO	diesel range organics
EIAP	Environmental Impact Analysis Procedures
EO	executive orders
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FEW	F. E. Warren Air Force Base
FFA	Federal Facilities Agreement
FS	Feasibility Study
GRO	gasoline range organics
HHRA	Human Health Risk Assessment
HI	hazard index
HQ	hazard quotient
I-25	Interstate 25
IRP	Installation Restoration Program
LOAEL	lowest observed adverse effects level
LTM	long term monitoring
MCL	maximum contaminant level
MW	monitoring well
NEPA	national environmental policy act
NCP	National Contingency Plan
NOAEL	no observed adverse effects level
NPDES	National Pollutant Discharge Elimination System

NPL	National Priorities List
NPV	net present value
O&M	operation and Maintenance
OU	operable unit
OSHA	occupational safety and health administration
PAHs	Polyaromatic hydrocarbons
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PPE	personal protective equipment
RAO	remedial action objective
RBC	risk-based concentrations
RCRA	resource conservation and recovery act
RI	Remedial Investigation
ROD	Record of Decision
SDWA	Safe Drinking Water Act
SF	slope factor
SSL	soil screening level
SVOC	semi-volatile organic compound
TBC	to be considered
TCE	trichloroethene
TPH	Total petroleum hydrocarbons
USFWS	U.S. Fish and Wildlife Service
UXO	unexploded ordnance
VOC	volatile organic compound
WAQSR	Wyoming Air Quality Standards and Regulations
WCA	waste consolidation area
WDEQ	Wyoming Department of Environmental Quality
WHWRR	Wyoming hazardous waste rules and regulations
WSWRR	Wyoming solid waste rules and regulations
WWQRR	Wyoming water quality rules and regulations

Preface

This Feasibility Study (FS) Report for Landfill 4 has been prepared for the U.S. Air Force Center for Environmental Excellence (AFCEE) by CH2M HILL, Inc. under Contract Number F41624-97-D-8019, Delivery Order Number 0190. The period of performance for this delivery order is from November 30, 2000, through February 28, 2004. The purpose of the proposed work is to define the nature and extent of environmental contamination at six Installation Restoration Program (IRP) Sites in Zone E (including Landfill 4), evaluate risks to human health and the environment, and evaluate appropriate remedial actions for cleanup of contamination. CH2M HILL's Project Manager for this contract is Gary Jardine, P.E., telephone (720) 286-5609. The AFCEE Contracting Officer's Representative (COR) for this effort is Ernesto Perez, telephone (307) 773-3468.

Executive Summary

This Feasibility Study (FS) identifies and evaluates remedial actions for Landfill 4 at F. E. Warren Air Force Base (FEW). The FS is prepared in response to remedial action objectives (RAOs) identified in the *Remedial Investigation (RI) Report, Zone E, Landfill 4, F. E. Warren Air Force Base, Wyoming* (USAF, 2002a). The FS report has been organized into five sections that are consistent with the U.S. Environmental Protection Agency's (EPA) *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988). The scope of the FS includes the landfill source area and associated groundwater.

Landfill 4 is comprised of two subunits containing solid wastes, Landfill 4a and Landfill 4b. No solid wastes were identified in a third subunit, Landfill 4c during the RI in 2001 (USAF, 2002a). Waste disposal operations began at Landfill 4 in 1947. Operations continued until the unit was closed in 1959, approximately the same time Landfill 5a began operations. Landfill 4 operated as a trench and fill-type operation.

Landfill 4a has two distinct areas where buried solid waste is present, encompassing approximately 17 acres. Landfill 4b also has two distinct areas containing buried solid waste, which together encompass approximately 8 acres. There are approximately 3 additional acres where surficial concrete and demolition debris have been placed along the southern boundary of Landfill 4a. Based on available FEMA mapping, approximately 9 acres of Landfill 4a are potentially located within the 100-year floodplain of Crow Creek. However, this estimate likely does not take into account changes in topography related to placement of fill material over the landfill between 1988 and 1990.

Solid waste streams identified in Landfill 4 were domestic wastes (paper, bottles, beverage cans, food containers, toiletries, housewares, and kitchenware) and light construction and industrial debris (metal fragments, concrete fragments, plywood, wire rope, conduit, nails, glass, and empty containers). No drums or large vessels were encountered during a trenching investigation, which would suggest that the landfill was used for disposal of industrial materials. A majority of the buried solid wastes were partially or completely burned as part of the disposal process, thereby greatly reducing the potential for further degradation of the waste. There is an estimated 110,000 cubic yards (cy) of buried solid wastes, intermixed soils, and native soils between waste trenches at Landfill 4. Two separate areas of unburned waste were observed, each covering less than 1 acre. Although not necessarily a source of environmental contamination, approximately 10,000 cy of concrete and demolition debris are present on the surface of the landfill, primarily on the south side of Landfill 4a.

RAOs identified for Landfill 4 were based on the nature and extent of contamination, the risks associated with the contaminants, the fate and transport of the contaminants, and compliance with federal and state applicable or relevant and appropriate requirements (ARARs). To reduce future risk to human health and the environment, the following RAOs are proposed for Landfill 4:

1. Limit potential for ponding of storm water on the landfill surface

2. Reduce the potential for erosion from wind and water
3. Limit potential for contact with landfill materials and groundwater that create a physical hazard to humans
4. Restore ground water to beneficial use, which in this case is restoration of iron and manganese to background conditions. The background concentrations are best evaluated through future monitoring to address temporal and spatial variations. If iron and manganese concentrations in groundwater at Landfill 4 are confirmed to be background through future monitoring, there will be no further requirement for restoration.

Based on the RAOs and applicable or relevant and appropriate requirements (ARARs), general response actions were identified and technology types and process options were screened. Five remedial alternatives were selected, developed, and analyzed. The alternatives were developed to address mainly landfill contents based on the presumption that iron and manganese concentrations in groundwater are naturally-occurring. If monitoring does not verify that iron and manganese are naturally-occurring, alternatives to address groundwater will be developed. The remedial alternatives are:

- Alternative 1 – No action
- Alternative 2 – Institutional controls
- Alternative 3 – Localized site improvements
- Alternative 4 – Engineered landfill cap (presumptive remedy which must be considered)
- Alternative 5 – Full excavation and disposal of landfill waste

Each alternative was analyzed and assessed with respect to nine evaluation criteria. The first two criteria (overall protection and compliance with ARARs) are threshold criteria. Any alternative must be both protective and comply with ARARs before it can be considered for a remedy. The next five criteria are balancing criteria, where the relative merits and tradeoffs among the criteria are evaluated. The final two criteria are modifying criteria, in which the state and the community express whether they support or oppose the alternatives, which are evaluated by the end of the public comment period.

Threshold Criteria:

- Overall protection of human health and the environment
- Compliance with ARARs

Balancing Criteria:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

Modifying Criteria:

- Agency acceptance
- Community acceptance

Alternative 5 is protective of human health and the environment by removing the landfill waste from the site and disposing of it in an approved landfill facility. Alternative 4 is protective by containing the landfill onsite, and also provides an additional measure of protection by installing a landfill cap specifically designed to minimize infiltration into the landfill. Alternative 3 meets this threshold criterion by addressing only those areas of the landfill where corrective measures are required to limit ponding of storm water on the landfill surface, address areas susceptible to erosion, and limit the potential for contact with landfill materials that create a physical hazard to humans. Each of these alternatives would incorporate institutional controls and inspection and monitoring programs to monitor the site stability and condition of groundwater.

Alternative 1 and Alternative 2 do not meet the threshold criteria for overall protectiveness of human health and the environment. Alternative 1 does not meet this threshold criteria because it does not meet any of the RAOs. Alternative 2 does not meet this threshold criteria because it would not limit the potential for ponding on the landfill surface or further reduce the potential for erosion from wind or water. Because Alternatives 1 and 2 do not meet this threshold criteria, it is not necessary to compare them with other alternatives as part a comparative analysis.

Alternatives 3, 4, and 5 all comply with the applicable contaminant-specific, action-specific, and location-specific ARARs identified for Landfill 4 as well as relevant and appropriate requirements of the Wyoming Solid Waste Management Rules and Regulations (WSWMRR).

Alternative 5 affords the highest degree of long-term effectiveness and permanence by physically removing landfill wastes from the site. Alternatives 3 and 4 are generally similar in being effective long-term onsite remedial alternatives. From a site stability perspective (e.g., limiting ponding of storm water, reducing erosion potential), Alternative 3 may be more effective than Alternative 4 because the loss of mature vegetation would be reduced and only localized areas would be addressed. Alternative 4 would require that the existing vegetation be destroyed and replaced with shallow-rooted grasses. Alternative 4 would also require that a significant amount of regrading and or fill material be placed, which may create additional future settlement across the site. Each of these alternatives would implement similar institutional controls and inspection and monitoring programs.

Alternatives 3, 4, and 5 would not reduce toxicity, mobility, or volume through treatment. However, these alternatives are intended to reduce contaminant mobility through containment. Alternative 5 is the most effective because the wastes would be disposed at an offsite landfill facility that would have a bottom-liner system in addition to a landfill cap. Alternative 4 may be more effective than Alternative 3 in reducing contaminant mobility because an infiltration barrier would be installed, whereas Alternative 3 relies more on the water storage capacity of the cover soil, and evapotranspiration processes.

Alternative 3 would have the least short-term impact on the community, workers, and the environment. Construction activities would be limited to localized areas around the landfill, and only identified unburned wastes would be exposed while excavating and loading trucks for offsite disposal. The reduced amount of hauling of borrow soil and wastes would limit the volume of truck traffic required to complete the alternative. Alternative 3 could also be completed in the shortest period (1 to 2 months) of the alternatives. Alternative 4

would have an increased short-term impact on the community, workers, and the environment. Alternative 4 would require the entire site be disturbed, resulting in increased potential for fugitive dust emissions. There would also be increased truck traffic required to transport up to 172,000 cy of borrow soils to construct the landfill cap. Alternative 4 could be completed within 3 to 6 months. Alternative 5 would have the greatest short-term impact on the community, workers, and the environment. Alternative 5 would also require disturbing the entire site, and handling of the greatest amount of landfill wastes, resulting in an increased exposure to contaminants. There would also be increased truck traffic to transport 120,000 cy of waste, concrete, and demolition debris to an offsite facility. Alternative 5 could be completed within 6 to 12 months.

Alternatives 3, 4, and 5 can be technically and administratively implemented. However, there are important technical uncertainties that differentiate the ability to effectively implement each alternative. Alternative 3 is the most efficient to implement with the fewest uncertainties, such as obtaining borrow soils, that could impact the level of effort and cost to complete. Alternative 4 could be implemented in a similar fashion to Alternative 3, but the level of effort is increased to complete the work, and there would be additional uncertainty in obtaining borrow soils for construction of the cap in near proximity to the landfill. Alternative 5 is the least implementable of the alternatives because of the increased level of effort required and the uncertainties in the amount of waste that would ultimately be disposed at an approved landfill facility.

The costs for each alternative are summarized below. Alternative 3 would have the lowest capital cost, approximately one-third of the cost for Alternative 4 and one-fourth of the cost for Alternative 5. The total O&M (i.e., inspection and monitoring) costs for Alternatives 3 and 4 are similar, except that additional site inspections would be required for Alternative 4 until the landfill cap stabilizes. The O&M costs for Alternative 5 are similar to the Alternatives 3 and 4, except that the number of monitoring well locations was reduced to assess the condition of groundwater and confirm that the vegetation is established after the waste is removed.

Alternative	Capital Cost	Total O&M Cost	Net Present Value (5.0% Discount Factor)
1. No Action	\$ 0	\$ 0	\$ 0
2. Institutional Controls	\$ 80,000	\$ 60,000	\$ 110,000
3. Localized Site Improvements	\$ 1,950,000	\$ 5,118,500	\$ 4,900,000
4. Engineered Landfill Cap	\$ 4,730,000	\$ 5,151,000	\$ 7,700,000
5. Excavation and Removal	\$ 8,200,000	\$ 3,006,000	\$ 9,900,000

SECTION 1.0

Introduction and Site Information

1.1 Purpose and Organization of Report

This Feasibility Study (FS) identifies and evaluates remedial actions for Landfill 4 at F. E. Warren Air Force Base (FEW). The FS is prepared in response to remedial action objectives (RAOs) identified in the *Remedial Investigation (RI) Report, Zone E, Landfill 4, F. E. Warren Air Force Base, Wyoming* (USAF, 2002a). The FS report has been organized into five sections that are consistent with U.S. Environmental Protection Agency's (EPA) *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988). These sections include:

- 1.0 – Introduction and Site Information
- 2.0 – Identification and Screening of Technologies
- 3.0 – Development and Screening of Alternatives
- 4.0 – Detailed Analysis of Alternatives
- 5.0 – References

Section 1.0 presents background information including the site description and history, summaries of the nature and extent of contamination, contaminant fate and transport, and the baseline risk assessment from the RI. Section 2.0 discusses the RAOs, applicable or relevant and appropriate requirements (ARARs), and general response actions. Section 2.0 also includes identification and screening of technology types and process options. Section 3.0 develops an appropriate range of waste management options that are analyzed more fully in the detailed analysis contained in Section 4.0. The detailed analysis of alternatives includes a presentation of the relevant information needed for decision makers to select a site remedy. Section 5.0 includes the references used to prepare this FS.

1.2 Background Information

Landfill 4 has been described in previous documents, including the 1991 Installation Restoration Program Remedial Investigation, the Final Work Plan, Remedial Investigation/Feasibility Study for Zone E, and Remedial Investigation Report, Zone E, Landfill 4 (USAF, 1991; USAF 2001; and USAF 2002a). This site history and findings of the RI are summarized below.

1.2.1 Base Background

FEW occupies 5,869 acres of high plains in southern-central Laramie County in southeastern Wyoming, immediately west of the City of Cheyenne. Agricultural land is located north and northwest of FEW, while rural housing borders FEW to the south and southwest. A site map for the base is shown in Figure 1-1.

FEW was placed on the National Priorities List (NPL) in February 1990, and in September 1991, FEW entered into a Federal Facilities Agreement (FFA) with the EPA and Wyoming Department of Environmental Quality (WDEQ). The FFA established the procedural framework and schedule for investigation and response actions in accordance with the National Contingency Plan (NCP), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) policy and guidance, Resource Conservation and Recovery Act (RCRA) policy and guidance, and applicable state laws.

The FEW IRP presently includes 20 sites. The sites are managed as 13 operable units (OUs) using a system of investigation zones (Zones A through E) to facilitate investigation and reporting. IRP sites currently under investigation within Zone E include groundwater at four Spill Sites (1, 3, 5, and 6), Landfill 4, and the OB/OD Area. Zone E site locations are shown on Figure 1-2. While the Firing Range is physically located within Zone E, the site is not part of the Zone E RI/FS. Further investigation of the Firing Range has been deferred until a later time because of complexities in the Range Rule and issues associated with gaining ordnance clearance (USAF, 2000b).

This FS only addresses Landfill 4. No remedial action objectives were identified for other sites in Zone E (USAF, 2002c).

1.2.2 Landfill 4

1.2.2.1 Site History

For the purpose of this FS, Subunits 4a and 4b will collectively be referred to as Landfill 4. A site map of Landfill 4 is shown on Figure 1-3.

Landfill 4 is located in the southeastern corner of the Base, near the entrance to Gate 2. During World War II, this area of FEW was used for bulldozer practice. Corresponding to the closure of Landfill 2c, waste disposal operations began at Landfill 4 in 1947. Operations continued until the unit was closed in 1959, approximately the same time Landfill 5a began operations. Landfill 4 operated as a trench and fill-type operation.

For the purpose of the RI, the landfill was divided into three subunits (4a, 4b, and 4c). Landfill 4a has two distinct areas where buried solid waste is present, encompassing approximately 17 acres. Landfill 4b also has two distinct areas containing buried solid waste, which together encompass approximately 8 acres. There are approximately 3 additional acres where surficial concrete and demolition debris have been placed along the southern boundary of Landfill 4a. It appears that Landfills 4a and 4b were historically a single landfill area. Aerial photographs indicate that a road (now referred to as Missile Drive) was constructed over the landfilled wastes between 1956 and 1960.

Landfill 4c is located west of Interstate 25 (I-25) and north of the railway, and comprised of approximately 8 acres. Landfill 4c was originally identified as a potential landfill area based on surficial debris. Intrusive investigation activities during the Zone E RI concluded that Landfill 4c was not used for waste disposal activities. No additional investigation activities were completed at Landfill 4c and the area will not be addressed as part of this FS.

1.2.2.3 Geologic Setting

Surficial deposits in most of the Landfill 4 area consist of Quaternary deposits that overlie the Tertiary Ogallala Formation. The contact is estimated to be the first distinct clay, silt, or sandy clay layer below the unconsolidated Quaternary deposits. Quaternary terrace deposits in the Landfill 4 area range in thickness from about 10 to 30 feet and consist of interbedded clay, sand, and gravel. Because the Landfill 4 area is located along and near Crow Creek, the Quaternary deposits are thicker than other areas at the Base, and the shallow monitoring wells (MWs) are completed mostly in the Quaternary deposits with some penetration into the Ogallala Formation. The Ogallala Formation beneath Landfill 4 is predominantly interbedded clayey sand, fine, sandy silt, and sandy clay, with several sandstone lenses. The general geology underlying Landfill 4 is shown in Figure 1-4.

1.2.2.4 Hydrogeologic Setting

The Quaternary deposits and upper portion of the Ogallala Formation (up to approximately 30 feet below ground surface) are hydraulically connected and form the unconfined shallow aquifer at Landfill 4. Together, these water-bearing strata are referred to as the High Plains Aquifer. The depth to groundwater ranges from approximately 2 feet below ground surface (bgs) to the south of Landfill 4 (near Crow Creek) to 18 feet bgs to the north of Landfill 4. Other water-bearing units occur within the Ogallala Formation. The first water-bearing unit (beneath the unconfined shallow aquifer) was referred to in the RI Report as the intermediate aquifer and occurs from approximately 40 to 60 feet bgs. The next water-bearing unit beneath Landfill 4 was referred to in the RI Report as the deep aquifer and occurs from approximately 80 to 100 feet bgs.

Water level measurements collected from shallow, intermediate, and deep monitoring wells at Landfill 4 during the Zone E RI indicate that there is a predominately upward groundwater gradient underlying the landfill (USAF, 2002a).

1.3 Nature and Extent of Contamination

The nature and extent of contamination described in this section pertains only to those contaminants subject to the RAOs identified in the Landfill 4 RI. For a comprehensive discussion of the nature and extent of all the contaminants identified within Landfill 4, refer to the Landfill 4 RI.

1.3.1 Lateral and Vertical Extent of Landfill 4

Landfill 4 is comprised of two subunits, Landfill 4a and Landfill 4b. Landfill 4a has two distinct areas where buried solid waste is present, encompassing approximately 17 acres. Landfill 4b also has two distinct areas containing buried solid waste, which together encompass approximately 8 acres. There are approximately 3 additional acres where surficial concrete and demolition debris have been placed along the southern boundary of Landfill 4a. Based on available Federal Emergency Management Agency (FEMA) mapping, approximately 9 acres of Landfill 4a are potentially located within the 100-year floodplain of Crow Creek. However, this estimate likely does not take into account changes in topography related to placement of fill material over the landfill between 1988 and 1990.

Aerial photographs and field trenching activities indicate that subunits 4a and 4b were historically a contiguous landfill area. The road (now referred to as Missile Drive) was constructed over the landfill wastes between 1956 and 1960. As-built drawings from the original road construction indicated that landfill waste was removed “from shoulder to shoulder” of the road, at least to the depth necessary to construct Missile Drive. For the purpose of the FS, it can be reasonably assumed that no waste is under the road, however, it is possible that the waste under the road was not completely removed.

There are generally two distinct zones within the landfill profile: cover soil and buried solid wastes. The cover soils are usually comprised of fill material, although miscellaneous hardfill (concrete and bricks) were encountered intermittently during the RI. There are areas across Landfill 4 (less than 10 percent) where the cover has settled creating the potential for water to pond on the landfill surface. Buried solid waste underlies the soil. Because buried solid wastes were present in narrow trenches (typically 3 to 6 feet wide), the soils intermixed with the waste as well as the native soils between the waste trenches are considered buried solid wastes. The estimated total depth of Landfill 4 was typically about 8 feet, with a maximum depth of approximately 12 to 14 feet. A summary of the thickness of cover soil and buried solid wastes is provided below. A typical landfill profile is provided in Figure 1-5.

Item	Vertical Thickness	Average Thickness
Cover Soil ¹	2 to 10 feet	5 feet
Buried Solid Wastes and Intermixed Soils ²	1 to 5 feet	3 feet

¹The average thickness of the cover soil was estimated by the following: (190,000 cy cover soil x 27 cf/1 cy)/(25 acres x 43,560 sf/acre)

²The average thickness of the buried solid waste and intermixed soils was estimated by the following: (110,000 cy buried solid wastes x 27 cf/1 cy)/(25 acres x 43,560 sf/acre)

The occurrence of buried solid wastes in contact with groundwater is most prevalent in Landfill 4a. Occurrences of groundwater or perched water observed in test trenches in Landfill 4b were infrequent and limited to the southeastern area of Landfill 4b near Gate 2. While difficult to accurately quantify, review of trench logs and water level data collected from monitoring wells suggests that 12 to 16 acres of buried solid waste in Landfill 4a (60 to 80 percent of the Landfill 4a area) may be in contact or in the immediate vicinity of underlying groundwater. Fluctuations in the groundwater table may increase or decrease this estimate significantly.

1.3.2 Contaminant Sources

The contaminant sources at Landfill 4 are related to buried solid wastes from past disposal activities between 1947 and 1959. Solid waste streams identified in Landfill 4 were domestic wastes (paper, bottles, beverage cans, food containers, toiletries, housewares, and kitchenware) and light construction and industrial debris (metal fragments, concrete fragments, plywood, wire rope, conduit, nails, glass, and empty containers). No drums or large vessels were encountered during the trenching investigation, which would suggest that the landfill was used for disposal of industrial materials. The findings of the trenching investigation in 2001 indicated that a majority of the buried solid wastes were partially or

completely burned as part of the disposal process, thereby greatly reducing the potential for further degradation of the wastes. There is an estimated 110,000 cubic yards (cy) of buried solid wastes, intermixed soils, and native soils between waste trenches at Landfill 4. Two separate areas of unburned wastes were observed, each covering approximately 1 acre. Although not necessarily a source of environmental contamination, approximately 10,000 cy of concrete and demolition debris are present on the surface of the landfill, primarily on the south side of Landfill 4a. The estimated volumes of cover soil, buried solid wastes, and surficial debris are summarized below. The basis for the volume estimates is provided in Appendix A.

Cover Soil/Waste Stream	Estimated Volume	Potential Variation in Volume Estimates
Cover Soil	190,000 cy	150,000 cy to 230,000 cy ¹
Buried Solid Waste(s)/Intermixed Soil ²	110,000 cy	70,000 cy to 150,000 cy ¹
Surficial Concrete/Demolition Debris	10,000 cy	5,000 to 15,000 cy ²
Estimated Total Volume of Soil and Waste Streams	310,000 cy	225,000 to 395,000 cy

¹Note that variations of ± 1 foot in assumed thickness may result in a difference of 40,000 cy over an approximate 25-acre footprint of buried solid wastes and cover soils.

²It was assumed that the quantity of surficial concrete and demolition debris may vary by a factor of 1.5.

1.3.3 Contamination Identified at Landfill 4

1.3.3.1 Waste

Organic Contaminants

Volatile organic compounds (VOCs) (25 analytes), semivolatile organic compounds (SVOCs) (35 analytes), pesticides (10 analytes) and polychlorinated biphenyls (PCBs) (3 analytes) were detected in waste samples at generally low concentrations. The detections of VOCs, SVOCs, pesticides, and PCBs were infrequent and generally of the same low magnitude. There does not appear to be an apparent trend to indicate a particular "hot spot".

Total petroleum hydrocarbon (TPH) diesel-range organics (DRO) detected in the waste ranged from non-detect to 1,180 milligrams per kilogram (mg/kg), below the WDEQ soil standard of 2,300 mg/kg. TPH gasoline-range organics (GRO) detected in the waste ranged from non-detect to 0.01 mg/kg, well below the WDEQ soil standard range of 28 to 15,600 mg/kg.

Inorganic Contaminants

Several inorganic compounds were detected in the waste at concentrations that exceeded the upper range of FEW background concentrations for subsurface soils. Antimony, arsenic, chromium, cobalt, copper, iron, lead, mercury, molybdenum, nickel, silver, sodium, and zinc each had more than one detection above the reference background range.

1.3.3.2 Waste Characterization

Analytical data for the 26 waste samples were compared to hazardous waste criteria for alternatives that require off-site disposal. Total concentrations of contaminants detected in waste samples were indirectly compared to toxicity characteristic (TC) criteria using the 20-to-1 division factor to estimate a theoretical leachate concentration. This division factor reflects the 20-to-1 ratio of extraction fluid mass to solid mass used in the Toxicity Characteristic Leaching Procedure (TCLP). The 20-to-1 division factor only establishes a threshold level based on total content of the analyte for when TCLP testing would be required, but does not mean that the waste would be characteristically hazardous. The following list summarizes individual waste samples where specific contaminants that may theoretically exceed the TC criteria using the 20-to-1 division factor.

Contaminant	Waste Sample Location	Waste Concentration (mg/kg)	Theoretical Leachate Concentration ¹ (mg/L)	Toxicity Characteristic Regulatory Level ² (mg/L)
Barium	W21	2,600	130	100.0
Chromium	W03	135	6.8	5.0
Mercury	W25	44	2.2	0.2
Selenium	W14	24	1.2	1.0
Lead	W01	383	19.2	5.0
	W02	224	11.2	
	W03	328	16.4	
	W04	325	11.2	
	W10	1450	72.5	
	W11	110	5.5	
	W14	3339	167	
	W17	900	45	
	W19	187	37.4	
	W22	145	7.3	
	W24	234	11.7	
	W25	1830	91.5	

¹Theoretical leachate concentration calculated by dividing the concentration detected in the waste by a factor of 20.

²Toxicity Characteristic Regulatory level from 40 CFR Part 261.24.

No samples exhibited the corrosivity characteristic (i.e., pH less than 2 or greater than 12) or the ignitability characteristic. Based on the data collected during the RI, additional TCLP

analysis would be required to definitively characterize waste designated for off-site disposal in the areas of the waste samples identified above.

1.3.3.3 Surface Soil

Organic Contaminants

SVOCs (14 analytes), pesticides (6 analytes), and PCBs (1 analyte) were detected in the surface soil at concentrations less than 1 mg/kg. These detections of SVOCs, pesticides, and PCBs were generally of the same magnitude, and no apparent trend was noted between surface soil samples collected within the footprint of Landfill 4 and surface soil samples collected immediately downwind of Landfill 4.

Inorganic Contaminants

Several inorganic compounds were detected in the surface soil at concentrations that exceeded the upper range of FEW background concentrations. Antimony, arsenic, barium, copper, lead, mercury, selenium, vanadium and zinc each had more than one detection above the reference background range. Because the surface soil covering Landfill 4 is from borrow sources from FEW or from regional offsite locations, some deviation from the range of FEW background concentrations is expected. The detections of metals in surface soil were generally of the same magnitude, and no apparent trend was noted between surface soil samples collected within the footprint of Landfill 4 and surface soil samples collected immediately downwind of Landfill 4.

1.3.3.4 Subsurface Soil

Organic Contaminants

VOCs (24 analytes), SVOCs (19 analytes), pesticides (5 analytes), and PCBs (1 analyte) were detected in the subsurface soil. VOCs, SVOCs, and PCBs were detected at concentrations less than 1 mg/kg. The concentrations of pesticides detected in the subsurface soil were less than 1 mg/kg, except for 4,4-DDD which was detected at 2.46 mg/kg. The detections of VOCs, SVOCs, pesticides, and PCBs in subsurface soils are infrequent and generally of the same low level magnitude.

Inorganic Contaminants

Inorganic compounds were detected in the subsurface soil at concentrations that exceeded the upper range of FEW background concentrations. However, only lead and mercury had more than one detection above the reference background range. The few individual exceedances of the FEW background range are considered to be within the variability of naturally occurring ranges, and suggests that the concentrations of metals in subsurface soils underlying Landfill 4 are naturally occurring.

There is no apparent trend to indicate that organic or inorganic contaminants identified in the waste have mobilized and partitioned into the subsurface soils underlying Landfill 4.

1.3.3.5 Groundwater

To assist with the interpretation of the nature and extent of groundwater contamination, groundwater analytical data collected during two sampling events in 2001 and 2002 were compared the range of concentrations observed in upgradient wells, maximum contaminant levels (MCLs), and Wyoming Department of Environmental Quality (WDEQ) groundwater

standards. Wells were grouped as being upgradient of Landfill 4, within (or underlying) Landfill 4, and downgradient of Landfill 4.

Organic Contaminants

Benzo(a)pyrene was the only organic compound detected in upgradient groundwater (in one sample, MW-281 collected July 2001) above screening criteria. The concentrations of benzo(a)pyrene (0.629 ug/L) slightly exceeded the MCL (0.2 ug/L).

The only organic compound detected in groundwater within Landfill 4 was chloroform, which did not exceed the MCL for total trihalomethanes.

Chloroform was not detected in groundwater downgradient of Landfill 4 (within the floodplain). However, other organic compounds (TCE and benzo(a)pyrene) were detected in downgradient groundwater at concentrations exceeding screening criteria. These organic compounds were not detected in groundwater within Landfill 4. Given the groundwater flow direction within the floodplain, the source of TCE is likely to be groundwater within the floodplain upgradient of Landfill 4. TCE Plumes C and E discharge to the floodplain and Crow Creek just upgradient of and adjacent to Landfill 4. TCE Plumes C and E are being investigated under a separate RI (USAF, 2002d). Benzo(a)pyrene was detected at a low concentration (below reporting limits) but above the MCL in downgradient groundwater at two locations (MW-058 and MW-283) during 2001. Benzo(a)pyrene was not detected in groundwater during 2002 or in any historic samples. Although the source of benzo(a)pyrene may be from Landfill 4 waste, the one time detection, low solubility, strong adsorption to soil and low mobility in groundwater indicates that benzo(a)pyrene is unlikely to be transported further downgradient.

Inorganic Contaminants

Aluminum, arsenic, iron, lead, and manganese were the only inorganic compounds in groundwater that exceeded their MCL and/or WDEQ groundwater standard. Lead, aluminum and arsenic were subsequently determined to be background using the distributional statistical tests (i.e., Wilcoxon Rank Sum and pooled t-test) outlined in the Baseline Risk Assessment Scoping Document for FEW (USAF, 2001b). For iron and manganese, the statistical tests indicated that there was a significant difference, which indicates that a release from the landfill may have occurred or the landfill has altered the geochemistry of the aquifer such that naturally occurring iron and manganese in the aquifer is released.

A graphical statistical technique (i.e., cumulative probability plots) was then used to further assess the concentrations of iron and manganese in groundwater at Landfill 4. The cumulative probability approach, in conjunction with an evaluation of geochemistry, takes into consideration natural variations in the groundwater flow path and natural influences from Crow Creek. The results of this analysis demonstrated that concentrations of iron and manganese are consistent with a single population originating from the aquifer mineralogy and do not represent a release from the landfill. In addition, the observed variations in the groundwater geochemistry were consistent with typical changes along a groundwater flow path and groundwater-surface water influences rather than influences from Landfill 4.

Although the RI report concluded that the concentrations of iron and manganese in groundwater are likely naturally occurring background concentrations, this is not certain because the high total organic carbon concentrations in groundwater, which influence the

iron and manganese concentrations, may either be naturally occurring or a result of the landfill waste. In addition, the source of the shallow groundwater beneath and downgradient of Landfill 4 may be a mix of groundwater from three different flow paths: (1) lateral groundwater flow from upgradient of the landfill; (2) upward groundwater flow from deeper water bearing units beneath the landfill; and (3) lateral groundwater flow in the floodplain adjacent to and parallel to Crow Creek, and flowing from upstream.

Additional groundwater (and corresponding surface water) monitoring was recommended in the RI to verify that the concentrations of iron and manganese are within the single background population observed during the RI and to assess whether or not the variations in geochemistry noted in groundwater are adversely influenced by Landfill 4.

1.3.3.6 Surface Water along Crow Creek

Surface water samples were collected upstream of Landfill 4, at intermediate locations, and downstream of Landfill 4 in 2001 and 2002. The range of constituents detected was compared to Wyoming Surface Water Quality Standards. Benzo(a)pyrene was the only organic compound detected above the surface water standard, but was only detected in the upstream sampling location. Manganese was the only inorganic compound detected above the surface water quality standard. However, the concentration of manganese exceeded the surface water standard in every sampling location and there was no apparent increase in manganese concentrations as surface water flowed by Landfill 4.

The results of the surface water sampling during the RI were also consistent with the results presented in the Surface Water and Sediment Risk Assessment completed at FEW, which concluded that there is no unacceptable risk to human health or ecological receptors from surface water at FEW, including Crow Creek (USAF, 2002b).

1.3.3.7 Sediments along Crow Creek

Sediment samples were collected at the same upstream, intermediate, and downstream sampling locations as the surface water samples in 2001 and 2002. Organic compounds were detected at low or non-detect concentrations in every sample location. Some inorganic compounds had individual exceedances of the background range, but these variations are likely the result of natural variation associated with the flow and depositional environment along Crow Creek.

The results of the sediment sampling during the RI were also consistent with the results presented in the Surface Water and Sediment Risk Assessment completed at FEW, which concluded that there is no unacceptable risk to human health or ecological receptors from sediments at FEW, including Crow Creek (USAF, 2002b).

1.4 Contaminant Fate and Transport

Polyaromatic Hydrocarbons (PAHs), which were detected in each medium, are considered relatively persistent in the environment. PAHs are relatively insoluble and strongly absorb to organic matter within the soil matrix and sediments. As a result, PAHs are not easily leached from soil and are not mobile in groundwater. PAHs were not detected in groundwater within Landfill 4 although they were detected in Landfill 4 waste and groundwater downgradient of Landfill 4. PAHs were not detected in groundwater during 2002 or in any historic samples. Although the source of PAHs may be waste from Landfill 4,

the one-time detection, low solubility, strong adsorption to soil and low mobility in groundwater indicate that benzo(a)pyrene is unlikely to be transported further downgradient.

TCE was detected in groundwater downstream of Landfill 4 and within Crow Creek. However, the source of TCE is likely to be TCE Plumes C and E discharging to Crow Creek. TCE is mobile in groundwater and degrades at relatively slow rates.

Inorganic constituents are persistent in the environment as they occur naturally as part of soil and rock minerals and are not degraded. The concentrations and mobility of inorganic contaminants in each medium are dependent on the solubility of the compound, soil-water partition coefficient and the geochemical conditions (e.g., pH and oxidation-reduction potential).

Iron and manganese are considered to be the only inorganic compounds at Landfill 4 that are potentially mobile in groundwater. Their mobility in groundwater is enhanced by the reduction in the oxidation state caused by natural microbial activity (as shown by naturally high TOC concentrations). Oxidation-reduction potential typically decreases from highly oxidized recharge zones to less oxidized zones in downgradient parts of a groundwater flowpath as dissolved oxygen is consumed by chemical reactions within the aquifer mineralogy and natural levels of microbial activity. The lower oxidized state, which occurs beneath and downgradient of some areas of Landfill 4, enhances mobility of iron and manganese. The results of the RI concluded that the changes in oxidation-reduction potential are most likely a result of naturally occurring conditions in the aquifer.

The maximum concentration of contaminants identified in Landfill 4 waste were compared to available Soil Screening Levels (SSLs) to assess the potential for compounds to be leached from waste to groundwater. For contaminants that had an SSL, the maximum concentration of 1,1-dichloroethene, 1,2-dichlorobenzene, 1,2-dichloroethane, 1,4-dichlorobenzene, 2,6-dinitrotoluene, 2-methylphenol, 4,4'-DDD, 4-chloroaniline, antimony, arsenic, barium, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, bis(2-chloroethyl)ether, cadmium, chromium, cyanide, dieldrin, indeno(1,2,3-C,D)pyrene, manganese, mercury, nickel, n-Nitro-di-n-propylamine, pentachlorophenol, selenium, silver, thallium, and zinc exceeded the corresponding SSL (DAF = 1), indicating that they have a potential to be leached from waste to groundwater at a concentration which may impact groundwater quality. As discussed in the RI, of these compounds that exceed the SSLs, only the concentrations of arsenic and manganese consistently exceed groundwater quality standards. However, arsenic is not considered to be contributed to groundwater from Landfill 4 waste, but instead is believed to be naturally occurring. Also, as discussed in Section 1.3.3.5, the concentrations of manganese in groundwater are considered to be background concentrations, although further monitoring is required to confirm this.

Transport of contaminants attached to soil particles by overland flow or by wind erosion are not considered to be important migration pathways due to the established vegetation and low concentration of compounds in surface soil. During flood conditions in Crow Creek, there is a potential for Landfill 4 waste to be transported to Crow Creek due to erosion of the landfill. The potential for this contaminant migration pathway to occur is considered low.

1.5 Baseline Risk Assessment

A baseline Human Health and Tier 1 Screening-Level and Ecological Risk Assessment were performed to evaluate the potential current and future risks associated with exposure to soil and groundwater at Landfill 4. The risk assessments used sampling and other site investigation data collected during the RI investigation in 2001 and 2002. These data are most representative of the current Landfill 4 conditions.

Exposure to surface water, sediment, and biota in the section of Crow Creek that runs past Landfill 4 is addressed in the Surface Water Risk Assessment (USAF, 2002c).

1.5.1 Human Health Risk Assessment

A Human Health Risk Assessment (HHRA) was performed to evaluate the potential current and future risks associated with exposure to environmental media of concern at Landfill 4. The HHRA was performed using the four major steps from the EPA and the Revised Baseline Risk Assessment Scoping Document (USAF, 2001b) standard-of-practice risk assessment methods.

1.5.1.1 Exposure Assessment

Landfill 4 currently consists of open range and unpaved roads. Missile Drive traverses the closed landfill. Air Force security personnel man the entrance to Gate 2 and monitor the numerous vehicles entering and leaving the Base. Other receptors that could potentially visit Landfill 4 are unauthorized personnel, security patrols, and environmental investigation workers. These receptors visit Landfill 4 on an infrequent basis. For the purpose of assessing risk at Landfill 4, it was conservatively assumed that the land in and around the landfill may be used in the future for occupational (i.e., commercial, industrial) or residential purposes. The following exposure scenarios were assessed quantitatively for Landfill 4:

- Current and future occupational workers assumed to work a hypothetical 8-hour shift for 25 years to address potential exposure to surface soil (0 to 2 feet bgs)
- Construction workers assumed to work for short durations over a 2-year period to address potential exposure to mixed-zone soil (0 to 10 feet bgs)

The following scenarios were evaluated for risk management purposes to identify whether institutional controls are needed or, if there is a change in land use, whether a remedy may need to be re-evaluated.

- Future onsite residential exposure scenario to address potential exposure to surface soil (0 to 2 feet bgs) and shallow groundwater underlying the site.
- Future onsite residential exposure scenario to address potential exposure to shallow groundwater downgradient of Landfill 4.

1.5.1.2 Summary of Human Health Risk Assessment

The EPA uses a target risk range of 1×10^{-6} to 1×10^{-4} for total excess lifetime cancer risks within which the agency strives to manage risks. The EPA uses a total hazard index (HI) greater than 1 as an indication that there may be a concern for adverse non-cancer health

effects. The results of the Human Health Risk Assessment for Landfill 4 are summarized below.

Scenario	Total Excess Lifetime Cancer Risk	Total Hazard Index
Future Occupational Exposure (surface soil)	0 ¹	0 ²
Future Construction Exposure (mixed-zone soil)	6×10^{-8}	0.01
Future Residential Exposure (surface soil)	0 ¹	0 ²
Future Residential Exposure (onsite groundwater)	6×10^{-9}	0.009
Future Residential Exposure (downgradient groundwater)	2×10^{-4} ⁽³⁾	0.1

Notes:

¹No carcinogenic COPCs identified in the surface soil

²No COPCs with reference doses identified in the surface soil

³Risk shown associated with low-level sporadic detections of PAHs and TCE.

Soils and Waste. Calculated risks associated with residential or occupational exposure to surface soils and construction worker exposure to soil and waste contaminants are below the target risk range and target HI within which the EPA strives to manage total excess lifetime cancer risks under the current landfill condition.

Groundwater. Human health risks were evaluated for a hypothetical future residential exposure to shallow groundwater underlying the footprint of Landfill 4 (i.e., onsite groundwater) and exposure to shallow groundwater immediately downgradient of Landfill 4 (i.e., downgradient groundwater). These exposure scenarios were evaluated for risk management purposes to identify whether institutional controls are needed or, if there is a change in land use, whether the remedy would need to be re-evaluated.

The risk assessment for exposure to groundwater at Landfill 4 indicates no unacceptable excess lifetime cancer risks for residential exposure to groundwater beneath Landfill 4. Although the total excess lifetime cancer risk for exposure to groundwater downgradient of Landfill 4 slightly exceeds the target risk range ($>1 \times 10^{-4}$), the chemicals of potential concern (COPCs) driving this cancer risk are either attributed to upgradient sources (TCE) or were unconfirmed low-level detections (benzo(a)pyrene and dibenz(a,h)anthracene). TCE detected downgradient of Landfill is attributable to upgradient IRP sites (TCE plumes C and/or E) which discharge to the Crow Creek floodplain upstream of Landfill 4, and migrates within the floodplain groundwater downgradient of Landfill 4. Benzo(a)pyrene and dibenz(a,h)anthracene were detected in 2001 at low concentrations (below the reporting limit) in groundwater wells downgradient of Landfill 4, but were not detected in historic groundwater samples (prior to 2001) or in groundwater samples collected in 2002. However, benzo(a)pyrene was detected in the waste and may be the source of the benzo(a)pyrene detected in wells close to the downgradient edge of Landfill 4 in 2001.

The HI for non-cancer risk for residential exposure to groundwater beneath and downgradient of Landfill 4 below the EPA target HI of 1. This HI is based on the manganese concentrations being presumed background.

Surface Water Sediment. Human health and ecological risks were not calculated for surface water and sediment in Crow Creek. A separate risk assessment completed for the entire Crow Creek drainage within FEW property concluded that there was no risk to human health or ecological receptors along Crow Creek caused by releases from IRP sites, including Landfill 4 (USAF, 2002b).

1.5.2 Tier 1 Ecological Risk Assessment

A Tier 1 Ecological Risk Assessment (Tier 1 ERA) was performed to evaluate the potential risks associated with exposure to surface soil and surface water at Landfill 4. The ranges of several federally listed threatened, endangered, or candidate species occur within FEW; therefore, risks (calculated as Hazard Quotients, or HQs; $HQ = [\text{exposure concentration}] / [\text{effects concentration}]$) to reproduction of these special-status species and other resident, non-special status species were assessed at Landfill 4.

HQs were calculated for the plant community, soil invertebrate communities, birds, and mammals. For the plant and soil invertebrate communities, possible risk was assumed when HQs exceeded 1. For birds and mammals, two benchmarks (no adverse effects level - NOAEL; lowest adverse effects level - LOAEL) were used to bracket three possible outcomes: No risk, possible risk, and probable risk. When exposure concentrations did not exceed the NOAEL, no risk is assumed. When exposure concentrations exceeded the NOAEL, but not the LOAEL, possible risk is assumed. When exposure concentrations exceeded both the NOAEL and the LOAEL, probable risk is assumed.

The results of the Tier 1 Ecological Risk Assessment indicate a possible risk to the ecological receptors evaluated (plant community, including the Colorado butterfly plant, the soil invertebrate community, birds, or mammals). Given the conservative nature of the Tier 1 assessment process, the conservative assumptions used, and the fact that HQs are generally low, it was considered very unlikely that identified possible risks to the ecological receptors are significant or require further action.

SECTION 2.0

Identification and Screening of Technologies

2.1 Introduction

RAOs are based on the nature and extent of contamination, the risks associated with the contaminants, the fate and transport of the contaminants, and compliance with federal and state ARARs. The nature and extent of contamination from Landfill 4 and the potential risk associated with the contamination were presented in Section 1.0. This section identifies the ARARs and defines the RAOs.

2.2 Remedial Action Objectives

2.2.1 Remedial Action Objectives

RAOs are medium-specific goals for protecting human health and the environment that assist in the development and evaluation of remedial action alternatives.

To reduce future risk to human health and the environment, the following RAOs are proposed for Landfill 4:

1. Limit potential for ponding of storm water on the landfill surface
2. Reduce the potential for erosion from wind and water
3. Limit potential for contact with landfill materials and groundwater that create a physical hazard to humans
4. Restore ground water to beneficial use, which in this case is restoration of iron and manganese to background conditions. Background conditions are best evaluated through future monitoring to address temporal and spatial variations. If iron and manganese concentrations in groundwater at Landfill 4 are confirmed to be background through future monitoring, there will be no further requirement for restoration.

The RAOs were developed primarily to address physical deficiencies in the current landfill, including surficial ponding of precipitation and exposed concrete and demolition wastes.

RAO 1 addresses contaminant mobility by limiting the potential for surface water to collect and infiltrate into the landfill, reducing the potential for contaminants to be leached from the landfill wastes. RAOs 2 and 3 reduce the potential for human exposure to contaminants in the future. RAOs 1, 2, and 3 can be monitored by site inspections after implementation of the remedy.

RAO 4 addresses the uncertainty associated with iron and manganese concentrations and geochemical influences (including upward groundwater gradients) on iron and manganese concentrations in groundwater beneath and downgradient of Landfill 4.

Although the concentrations of some compounds (e.g. manganese) in Crow Creek surface water exceeded the surface water standards both upstream and downstream of Landfill 4, the RI did not show that Landfill 4 contributed to contaminants in Crow Creek. Therefore, an RAO to address surface water is not required. However, future monitoring of surface water in Crow Creek in conjunction with the groundwater monitoring specified in RAO 4 would confirm whether or not future exceedances, if any, are related to Landfill 4.

2.2.2 Applicable or Relevant and Appropriate Requirements

Landfill 4 is listed as an IRP site under the Superfund program, and it is USAF policy to follow the NCP and relevant CERCLA guidance in the IRP. Section 121(d)(2) of CERCLA requires that federal and state ARAR standards be identified for any proposed remedial actions, and that response actions achieve compliance with the identified ARARs. This requirement makes CERCLA response actions consistent with pertinent federal and state environmental requirements as well as adequately protecting public health and the environment. Criteria, advisories, and guidelines that are not law may be used to provide guidance in the absence of ARARs or when ARARs are not sufficient to protect human health and the environment. These criteria, advisories, and guidelines are in the “to be considered” (TBC) category.

ARARs are generally divided into three categories: 1) chemical-specific, which may allow or prohibit chemicals to exist in the environment at a particular level; 2) action-specific, which may require or prohibit certain actions; and 3) location-specific, which may require or prohibit actions based on location. Many of the regulations have interrelated chemical-, action-, and location-specific standards, criteria, or limitations. Categorization within this FS is based mainly on which predominates. In some cases, a citation may be repeated, but with the particular chemical-, action-, or location-specific portion described. Federal, state, and local regulations, requirements, criteria, and limitations were evaluated to determine if they are potentially applicable or relevant and appropriate to the screened alternatives in this FS.

2.2.2.1 Potential Applicable or Relevant and Appropriate Requirements

The following paragraphs list the potential federal and state ARARs identified for Landfill 4. A more detailed analysis of ARARs is presented in Section 4.0.

2.2.2.1.1 Chemical-Specific ARARs

The potential chemical-specific federal ARARs at Landfill 4 in Zone E include the following:

- *National Pollutant Discharge Elimination System (NPDES)*. The NPDES program establishes requirements to set water quality standards for all contaminants in surface water. Discharges of contaminated water from Landfill 4 will be treated and/or disposed of in general accordance with the requirements of the NPDES program.
- *Safe Drinking Water Act (SDWA)*. The SDWA establishes MCLs to protect the quality of drinking water in the United States. During the RI, contaminant detections in each media were initially screened against criteria including MCLs and WDEQ groundwater standards.

The potential chemical-specific state ARARs at Landfill 4 in Zone E include the following:

- *Wyoming Air Quality Standards and Regulations (WAQSR)*. The WAQSR establish ambient air standards for particulate matter and other air pollutants for the protection of air quality.
- *Wyoming Water Quality Rules and Regulations (WWQRR)*. The WWQRR establish human health- and aquatic life-use protective concentration limits for specific contaminants where contaminants may enter surface water or groundwater.

Chemical-specific federal and state ARARs are described in more detail in Table 4-3 and evaluated more fully in Section 4.0 of this FS.

2.2.2.1.2 Action-Specific ARARs

Potential action-specific federal ARARs include the following:

- *National Pollutant Discharge Elimination System (NPDES)*. Construction activities that disturb more than 5 acres of land are subject to the storm water provisions of the NPDES program, which set standards for the control of erosion and water quality effluent from construction sites. Landfill 4 may require land disturbance of greater than 5 acres and will discharge storm water in general accordance with the provisions of the NPDES program.
- *Occupational Safety and Health Administration (OSHA)*. OSHA rules are promulgated under Title 29 of the Code of Federal Regulations (CFR). Title 29 CFR establishes requirements for recording on-the-job injuries (Part 1904), occupational safety and health standards for personal noise and dust exposure (Part 1910), and safety and health regulations for construction (Part 1926).

Potential action-specific state ARARs include the following:

- *Wyoming Air Quality Standards and Regulations (WAQSR)*. The WAQSR establishes requirements for the control of particulate emissions and provides ambient air standards for odors.
- *Wyoming Solid Waste Rules and Regulations (WSWRR)*. Identify operation and closure requirements for sanitary, industrial, and construction/demolition landfills.
- *Wyoming Hazardous Waste Rules and Regulations (WHWRR)*. Identify and list hazardous waste and provide standards for hazardous waste generators, transporters, owners, and operators of hazardous waste treatment, storage, and disposal facilities.
- *Wyoming Water Quality Rules and Regulations (WWQRR)*. Identify procedures for surface water sampling and establish permitting requirements for discharges of pollutants to groundwater. These rules also establish standards for the design, construction, and abandonment of monitoring wells.

The concentrations of contaminants detected in Landfill 4 waste indicate that most, if not all, would be characterized as nonhazardous waste. Any hazardous waste encountered during the remedial actions will be managed according to the WHWRR requirements.

Action-specific federal and state ARARs are described in more detail in Table 4-4 and are further analyzed in Section 4.0.

2.2.2.1.3 Location-Specific ARARs

The potential location-specific federal and state ARARs may include some of the same statutes listed in the action-specific ARARs, as well the following:

- *National Environmental Policy Act and Environmental Impact Analysis Procedures (NEPA and EIA)*. These rules provide an environmental impact analysis process to help federal officials make decisions that are based on an understanding of environmental consequences.
- *Endangered Species Act*. Requires that federal activities not jeopardize the continued existence of any threatened or endangered species.
- *Archaeological and Historic Preservation Act*. Establishes procedures for preservation of historical and archaeological resources when terrain is altered as a result of a federal or federally licensed construction activity.

Location-specific state ARARs include:

- *Wyoming Water Quality Rules and Regulations (WWQRR)*. The classification of Crow Creek establishes location-specific water quality standards for any potential discharges from Landfill 4. The WWQRR provide standards for protection of wetlands and provide classification categories for streams.

Location-specific federal and state ARARs are discussed in more detail in Table 4-5 and are analyzed in Section 4.0 of this FS.

2.2.2.1.4 Potential Wyoming Relevant and Appropriate Requirements

Since the operation and closure of Landfill 4 predates state regulations that guide the operation and closure of sanitary landfills, these regulations are generally not applicable to Landfill 4. However, some sections may be relevant or appropriate to consider in evaluating remedial alternatives for landfill wastes and impacted soils. Potential relevant and appropriate state requirements were identified in Chapter 2 of the Wyoming Solid Waste Management Rules and Regulations, which regulates location, permitting, construction, operation, monitoring, and closure of sanitary landfills. These requirements are listed and described in Table 4-6 and are analyzed in Section 4.0 of this FS.

2.2.2.1.5 Guidelines To Be Considered (TBC)

TBC criteria are non-promulgated, non-enforceable guidelines or criteria useful for developing a remedial action or necessary for evaluating what protects human health and/or the environment. Examples include EPA drinking water health advisories, reference doses, and cancer slope factors (SFs). TBCs for Landfill 4 include EPA Presumptive Remedy guidance and USAF guidance documents as well as Wyoming's Voluntary Remedial Action Program (WVRAP). Although the exclusion of CERCLA sites from the WVRAP does exclude it as an ARAR, it does not preclude the use of some of the standards where they are useful, such as where there are no other promulgated standard or risk-based concentration.

2.2.3 Landfill 4 ARARs

Tables 4-3 through 4-6 in Section 4 of this FS summarize ARARs to be applied for remedial alternatives selected for Landfill 4. Within each table, federal ARARs are grouped according

to whether they are applicable or relevant and appropriate. The state requirements are separated according to media (air, water, waste) requirements.

2.3 General Response Actions

General response actions are medium-specific response categories that will satisfy the RAOs and were selected to satisfy the remedial objectives outlined in Section 2.3 by reducing the likelihood of contact with material found at Landfill 4. They include actions such as engineering improvements, containment systems, and waste removal. Although one response action may meet the RAOs, a combination of response actions may meet the goals more effectively. The integration of response actions into overall remedial alternatives is presented in Section 3.0 of this FS. The alternatives are being developed to address mainly landfill contents based on the presumption that iron and manganese concentrations in groundwater are naturally-occurring. If monitoring does not verify that iron and manganese are naturally-occurring, alternatives to address groundwater will be developed.

The general response actions identified for Landfill 4 are as follows:

No Action. Consists of taking no further action with respect to Landfill 4. The no action alternative is required by the NCP to provide a baseline for comparison of the other alternatives.

Institutional Controls. Legal and/or administrative controls to restrict or prevent present and future use and reduce exposure to landfill contaminants.

In Situ Remediation. In Situ controls are on-site measures to isolate the landfill contents and reduce the potential for offsite migration of landfill contaminants. Includes use of surface controls and cover systems.

Ex Situ Remediation. Ex Situ measures are off-site measures, include excavation and removal of landfill contents, treatment (if necessary), and/or disposal.

2.4 Identification and Screening of Technology Types and Process Options

This section presents the results of development and evaluation of remedial technologies. Remedial technologies are the methods by which the general response actions may be applied. Process options are the specific processes within a technology type by which the technology may be implemented. Once the technology types and process options are identified, they are evaluated on the basis of technical implementability, without considering effectiveness or cost.

2.4.1 Identification and Screening of Technologies

The technology types and process options identified for screening were:

- No action
- Institutional controls, such as access restrictions and restrictive covenants
- In situ remedial technologies such as surface controls and containment

- Ex Situ remedial technologies such as excavation and removal

The technology types and process options identified for Landfill 4 represent a range of remedial technologies and configurations that would potentially satisfy the RAOs identified for the site. Remedial technologies and process options corresponding to general response actions for Landfill 4 are presented in Table 2-1.

2.4.2 Evaluation of Technologies and Selection of Representative Technologies

For the purpose of this FS, each of the above technologies and process options is retained for further consideration as key components and/or elements of a removal action alternative. The next stage in the alternative development is screening of the retained technologies and process options. This evaluation uses the criteria of effectiveness, implementability, and cost to select the most promising process options within a technology type. Evaluations are based on engineering judgment, and the process options are scored on a comparative scale (i.e., high, medium, and low) relative to other process options within a particular technology type. The definitions of effectiveness and implementability are defined in Section 4.0.

The results of the process option evaluation are provided in Table 2-2. For technology types with only one process option, the effectiveness, implementability, and cost scorings represent a relative comparison between technology types. For these technology types, the sole process option identified was retained for analysis.

Based on the evaluation, the process options retained for assembly into alternatives for Landfill 4 are as follows:

- No action
- Institutional controls
- Localized site actions, including waste excavation and removal, waste consolidation, grading, cover soil, and revegetation as needed
- Engineered landfill cap (presumptive remedy which must be considered)
- Full Excavation and disposal of landfill waste

SECTION 3.0

Development and Screening of Alternatives

This section develops the remedial alternatives by combining the remedial technologies and process options that were carried forward from the screening process described in Section 3.2.

Five remedial alternatives were evaluated as part of this FS. The alternatives represent reasonable and practical remedial approaches that are consistent with the complexity of the site and EPA guidance in the NCP (40 CFR 300.430 (e)) and in the preamble in the *Federal Register*, 55 FR 8704.

3.1 Development of Alternatives

3.1.1 Alternative 1 – No Action

Alternative 1 consists of leaving the landfill in its current location and condition. Access to and use of the landfill area would not be further restricted. No groundwater monitoring or long-term operations and maintenance programs would be conducted. Because this alternative does not allow unrestricted use and unlimited exposure, this alternative would be subject to review not less than every five years. The no-action alternative is included as required by the NCP to provide an absolute no-action alternative for comparison purposes.

3.1.2 Alternative 2 – Institutional Controls

Alternative 2 consists of physical and/or institutional controls to limit access and future development at Landfill 4. The Landfill 4 area will be permanently identified as a landfill area, which will need to be maintained for the foreseeable future. Access to the area will be controlled and activities inconsistent with the maintenance of the landfill will be prohibited. Because this alternative does not allow unrestricted use and unlimited exposure, this alternative would be subject to review not less than every five years.

3.1.3 Alternative 3 – Localized Site Improvements

This alternative consists of addressing areas of Landfill 4 that do not satisfy the RAOs identified in Section 2.2, establishing institutional controls, and implementing a long-term monitoring program. Site improvements will consist of surface controls to establish positive drainage patterns across the landfill, excavation and removal activities, waste consolidation, site restoration, and institutional controls. Because this alternative does not allow for unrestricted use and unlimited exposure, this alternative will be subject to review not less than every five years. The primary components of this alternative are described below. Figure 3-1 depicts the conceptual site plan where site improvements are proposed.

Surface Controls

Surface controls will primarily involve placing some additional soil cover and/or regrading in areas that have settled to establish positive drainage patterns across the landfill. Based on visual inspection of the landfill, approximately 6,000 cy of soil fill may be needed to address approximately 3 acres (six localized areas) lacking positive drainage. At least 30 inches of cover soil will be maintained over areas that have been regraded. For the purpose of this FS, it is assumed that fill materials will be from an off-base borrow source, unless excess soils are generated as part of regrading activities.

Where necessary, areas of the landfill where other visible deficiencies are observed, such as surface cracks in the cover soils, measures will be taken to consolidate the underlying buried solid wastes and reduce the soil voids that may cause future settlement. These measures may include temporarily excavating the cover soils and compacting the underlying wastes in place, and/or removing and disposing of wastes that are not conducive to compaction (i.e., large debris such as broken concrete). Additional compactive efforts may also be applied to these areas of the landfill to reduce the potential for future settlement.

Waste Excavation and Removal

Waste Excavation and removal activities will include excavating the surficial concrete, demolition debris, and two localized areas identified during the RI. One area of unburned waste is located where methane was detected during a soil gas investigation in 1993. The other area is "stockpiled" waste east of Landfill 4b, which could erode in the future. Three waste samples were collected in these areas during the RI (samples W21, W23, W28, see Figure 3-1). Only sample W21 does not pass the 20-to-1 comparison for TC barium as presented in Section 1.3.2.2. Additional TCLP sampling for barium would be needed for this general area for waste characterization and disposal. For the sake of cost estimation, it is assumed that 95 percent of the wastes are considered to be non-hazardous and five percent of the waste be managed as hazardous. Non-hazardous wastes could be disposed at the North Weld Landfill near Ault, Colorado, approximately 40 miles south of the Base. Hazardous wastes would need to be disposed at an approved hazardous waste landfill or treated (e.g. stabilized) such that the wastes could be managed at North Weld Landfill. However, if available space and other considerations allow, the on-base Waste Consolidation Area (WCA) could also be used for some or all of the excavated waste. Recycling of the concrete debris may also be considered if an approved recycler and/or reuse option is identified during implementation.

Waste Consolidation

Concrete debris, demolition debris, and other inert wastes identified for offsite disposal may also be consolidated onsite. Such materials may be used as backfill for excavations and/or low spots identified during implementation. In any case, a minimum of 30 inches of cover soil will be placed over such wastes, which would meet the minimum thickness requirement for sanitary landfills in Wyoming and provides adequate separation between the waste material and potential receptors. The cover would be placed, compacted in lifts, and graded to drain, but would not need to meet a specific permeability requirements because the landfill is not being capped with a low permeability cover, as proposed in Alternative 4. The

allowance of waste consolidation will potentially reduce the disposal effort and associated cost.

Site Restoration

Minor debris (i.e., metal scrap, bricks, etc.) on the surface of the landfill after implementation of the remedy will be removed as a general “housekeeping” measure. Areas disturbed by implementation of the remedy will also be revegetated. Areas near Crow Creek would be revegetated with native grasses, brushes, and tall herbaceous species similar to the existing habitat. Upland areas would be revegetated with native prairie grasses.

Inspections and Monitoring

Landfill inspection and maintenance and a groundwater and surface water sampling program will be implemented after completing the construction activities. For the purpose of this FS, the duration of these activities is assumed to be 30 years.

Landfill inspection and maintenance activities (as needed) will include quarterly inspections during the first three years after implementing the alternative, and semi-annual inspections for the following 27 years. The inspections are intended to evaluate the integrity and stability of the existing landfill cover, particularly where grading and re-vegetation activities occurred. The inspections will include evaluation of vegetative cover (e.g., photo documentation), visual inspection for areas of settlement that allow ponding and greater potential for percolation of precipitation into the waste, and areas of potential erosion. Landfill inspection and maintenance activities will be documented in a site inspection report.

A comprehensive thirty year groundwater and surface water monitoring plan for this alternative is provided in Appendix B. The monitoring program is initially intended to address the requirements of RAO 4 and subsequently monitor the long-term effectiveness of the alternative. During the first three years following implementation of the alternative, monitoring will be completed on a quarterly basis to address RAO 4. Additional monitoring wells will be installed during implementation of the alternative to support the groundwater monitoring activities proposed.

The twelve quarters of monitoring data will be used to verify that the concentrations of iron and manganese are naturally occurring and that the landfill is not adversely impacting the geochemistry of the groundwater system. The results of the first three years of monitoring will be documented in a report for EPA and WDEQ review and concurrence.

Assuming that the requirements of RAO 4 are addressed during the first three years of monitoring, subsequent long-term monitoring will be completed on an annual basis for 27 additional years to monitor the effectiveness of the remedy. Long-term sampling activities will be documented in an annual report. A comprehensive assessment of the data collected will be completed after five years to determine if future monitoring is warranted.

As described in Appendix B, the monitoring network will include up to 31 monitoring wells and four surface water sample locations along Crow Creek. Samples will be analyzed for metals (total and dissolved), major cations and anions, VOCs, SVOCs, total suspended solids (TSS), total dissolved solids (TDS), total organic carbon (TOC), nitrate, nitrite, and total Kjeldahl nitrogen. The number of sample locations and analyses may also be reduced

based on monitoring results. Any changes in the monitoring program will be documented in the annual report for EPA and WDEQ review and concurrence.

Institutional Controls

Because the landfill will remain in place, additional institutional controls will be implemented as described in Alternative 2.

3.1.4 Alternative 4 – Engineered Landfill Cap

Section 300.430(a)(iii)(B) of the NCP includes the expectation that engineering controls, such as containment, be used for waste that poses a relatively low long-term threat and where treatment is impractical. As such, the “presumptive remedy” for municipal (and most military) landfills is containment (e.g., low-permeability cap). Because this alternative does not allow for unrestricted use and unlimited exposure, this alternative will be subject to review not less than every five years. The primary components of this alternative are described below. A conceptual site plan and typical landfill cap sections are provided in Figures 3-2 and 3-3.

Site Preparation

In order to construct a landfill cap, the established trees and woody vegetation within the footprint of the landfill will need to be cut down and shredded. In addition, up to nine existing source area monitoring wells may be abandoned during implementation of the alternative.

Waste Consolidation

Under this alternative, the two isolated areas of buried solid wastes (described in Alternative 3) would be consolidated under the cover. Surface concrete could be reused as cleaned fill material. Demolition debris would be consolidated in a similar fashion and covered with additional cover soil. The allowance of waste consolidation will potentially reduce the disposal effort and associated cost. Approximately 24,000 cy of solid waste, concrete debris, and demolition waste will be consolidated and used as fill under the landfill cap, as described below.

Landfill Cap System

The engineered landfill cap would be consistent with the Wyoming Solid Waste Rules and Regulations (WSWRR), Chapter 2, Section 7, for current sanitary landfills in the state of Wyoming. The WSWRR specify that landfill caps include at a minimum 2-foot-thick infiltration barrier layer and 6 inches of topsoil. The infiltration barrier with a minimum permeability less than or equal to 1×10^{-5} cm/sec. A 3 percent minimum slope will also be established by regrading the existing cover soils and importing fill to establish grade as recommended by WDEQ Solid Waste Guideline No. 16.

Based on the conceptual design for this alternative, the landfill cap will encompass approximately 23 acres of Landfill 4. Approximately 79,000 cy of imported soil fill will be needed to establish the minimum 3 percent grades; 74,000 cy of compacted clay will be required for the infiltration barrier; and 19,000 cy of topsoil will be required for the cover

over the infiltration barrier. This equates to approximately 172,000 cy of borrow material required to construct the landfill cap.

Site Restoration

The landfill cap would be revegetated with shallow-rooted native grasses to reduce the potential for wind and water erosion. The proposed minimum grade of the landfill cap would be three percent and would eliminate the existing steep embankment on the south side of landfill 4 along Crow Creek. Proper revegetation should be sufficient to protect the cap during a flood event because of its low profile, however if it is not sufficient, rip-rap shall be placed to prevent erosion.

Inspections and Monitoring

Landfill inspection and maintenance and a groundwater and surface water sampling program will be implemented after completing the construction activities. For the purpose of this FS, the duration of landfill inspection and maintenance activities is assumed to be 30 years to ensure that the landfill cap is functioning properly. The groundwater and surface water sampling program will be implemented for thirty years.

Landfill inspection and maintenance activities (as needed) will include quarterly inspections during the first three years after implementing the alternative, and semi-annual inspections for the following 27 years. The inspections are intended to evaluate the long-term integrity and stability of the newly installed landfill cap. The inspections will include evaluation of vegetative cover (e.g., photo documentation), visual inspection for areas of settlement that allow ponding and greater potential for percolation of precipitation into the waste, and areas of potential erosion. Landfill inspection and maintenance activities will be documented in inspection reports.

The groundwater and surface water sampling program is the same as for Alternative 3. For the purpose of this FS, it is assumed that the sampling program will be completed over a thirty year period following implementation of the alternative. Because this alternative does not allow for unrestricted use and unlimited exposure, this alternative will be subject to review not less than every five years.

Institutional Controls

The institutional controls for this alternative are equivalent to the institutional controls described for Alternatives 2 and 3.

3.1.5 Alternative 5 – Full Excavation and Disposal

Alternative 5 consists of excavating and disposing solid wastes (and intermixed soil) at Landfill 4. The primary components of this alternative are described below.

Site Preparation

In order to safely implement the work, the established large trees and woody vegetation would need to be cleared from within the landfill. The vegetation may be stockpiled and used for mulch during site restoration activities. In addition, up to nine source area monitoring wells would be abandoned as part of this alternative.

Excavation and Disposal

This alternative would be implemented by excavating, segregating, and temporarily stockpiling the cover soils that overlie the solid wastes. After excavating the cover soil, the solid wastes and intermixed soils would be excavated and transported to a disposal facility that can accept the wastes. For the sake of cost estimation, it is assumed that 95 percent wastes are considered to be non-hazardous and five percent of the waste be managed as hazardous. Additional TCLP analysis for the specific constituents and sample locations identified in Section 1.3.2.2 would be needed for waste characterization and disposal. Non-hazardous wastes could be disposed at the North Weld Landfill near Ault, Colorado, approximately 40 miles south of the Base. Hazardous wastes would need to be disposed at an approved hazardous waste landfill or treated (e.g. stabilized) such that the wastes could be managed at North Weld Landfill.

Implementation of this alternative would require excavation and temporary storage of up to 190,000 cy of cover soils. An estimated 120,000 cy of buried solid waste/intermixed soil, concrete, and demolition debris would be excavated and transported to an approved offsite disposal facility. Some de-watering measures (i.e., temporarily stockpiling on-site) may also be required for waste that is in contact with groundwater, particularly in Landfill 4a. Dewatering operations that potentially require discharge to Crow Creek may require treatment of the water before discharge. Groundwater would require treatment for the following compounds (i.e. maximum concentrations of compounds in groundwater which exceed Chapter 1 standards for a Class 2AB stream): benzo(a)pyrene, aluminum, arsenic, chromium, iron, lead, manganese, and mercury.

The stockpiled cover soils would then be used as fill to re-establish drainage patterns at the site and match existing grades along Missile Drive and near Crow Creek. There is an inherent level of uncertainty in the volume estimates, and a variation of 1 foot in thickness may result in a difference of 50,000 cy over the footprint of Landfill 4.

Buried solid wastes, if present beneath Missile Drive, would not be excavated as part of this alternative. The existing pavement and road fill that comprise Missile Drive provide an effective barrier for reducing infiltration into the landfill wastes. For the wastes left underneath Missile Drive, at least 30-inches of cover soil on either side of Missile Drive would be placed over the waste.

Site Restoration

It is likely that this alternative would be implemented in a progressive fashion, whereby cover soil is excavated and immediately reused as fill material in areas where the waste has been removed, thereby reducing the size and volume of temporarily stockpiled soil fill.

After final grades are established, the entire disturbed area would be revegetated. Areas adjacent to Crow Creek would be revegetated with native grasses, brushes, and tall herbaceous species similar to the existing habitat. Upland areas would be revegetated with native prairie grasses.

Inspections and Monitoring

Landfill inspection and maintenance and a groundwater and surface water sampling program will be implemented after completing the construction activities. For the purpose

of this FS, the duration of these activities is assumed to be thirty years. LTM activities will include inspections and maintenance (as needed) of the restored area and groundwater and surface water monitoring.

Inspection and maintenance activities will include quarterly inspections during the first three years following implementation of the alternative, and semi-annual inspections for the following 27 years. The inspections are intended to evaluate the integrity and stability of the restored surface as it stabilizes. The inspections will include evaluation of vegetative (i.e., photo documentation) and visual inspection for areas of potential erosion that could adversely impact Crow Creek. Inspection and maintenance activities will be documented in an inspection report.

The groundwater and surface water sampling program is similar to Alternatives 3 and 4. Data collected during the first three years of quarterly sampling will be used to verify that the concentrations of iron and manganese are background. The potential for the landfill to adversely impact the geochemistry of the aquifer will be eliminated by removing the wastes. The results of the first three years of monitoring will be documented in a report for EPA and WDEQ review and concurrence. The subsequent 27 years of annual sampling will be used to demonstrate that the excavation activity did not cause contaminants in the waste to be mobilized to groundwater and/or contaminants in groundwater are not migrating to Crow Creek. Sampling activities will be documented in an annual report. This alternative will be subject to review not less than every five years if any waste was left in place and until metals concentrations in groundwater are established as background or restored through a remedy. A comprehensive assessment of the data collected will be completed after 5 years to determine if future monitoring is warranted.

Three upgradient monitoring wells (MW-280, MW-080, and MW-281RR), seven downgradient monitoring wells (MW-812, MW-058, MW-811, MW-148, MW-059R, MW-283, and MW-060R), and four surface water sample locations along Crow Creek are proposed for groundwater and surface water monitoring (see Figure 1-3). No additional monitoring wells, such as source area wells, are proposed for this alternative because the landfill waste would be removed. Samples will be analyzed for metals (total and dissolved), major cations and anions, VOCs, SVOCs, total suspended solids (TSS), total dissolved solids (TDS), total organic carbon (TOC), ammonia, nitrate, nitrite, and total Kjeldhal nitrogen. The number of sample locations and analyses may be reduced based on monitoring results. Any changes in the monitoring program will be documented in the annual report for EPA and WDEQ review and concurrence.

Institutional Controls

The institutional controls for this alternative would be limited to groundwater use restrictions until sufficient groundwater data are collected to ascertain if groundwater was adversely impacted by the landfill. Institutional controls would also be required if any waste was left in place, particularly if excavation along the shoulder of Missile Drive becomes problematic for reasons such as road stability concerns or Base use of the road.

3.2 Screening of Alternatives

Five alternatives have been developed to address the RAOs at Landfill 4. The alternatives include no action and the presumptive remedy of capping, as required by the NCP. Given the limited number of alternatives, it is not necessary to screen out any alternative to reduce the number of alternatives that will be analyzed in detail. Each alternative will be carried forward to the Detailed Analysis of Alternatives in Section 4.0.

SECTION 4.0

Detailed Analysis of Alternatives

4.1 Introduction

This section presents the individual analysis and assessment of each groundwater alternative with respect to the nine evaluation criteria from the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR Part 300 (EPA, 1998). The nine evaluation criteria are:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State agency acceptance
- Community acceptance

The first two criteria (overall protection and compliance with ARARs) are threshold criteria. Any alternative must be both protective and comply with ARARs before it can be considered for a remedy. The next five criteria are balancing criteria, where the relative merits and tradeoffs among the criteria are evaluated. The final two criteria are modifying criteria, in which the state and the community express whether they support or oppose the alternatives, which are evaluated by the end of the public comment period. The threshold and balancing criteria are further described in Table 4-1.

Following the individual analysis for each alternative is a comparative analysis among the alternatives. The comparative analysis will assess the relative performance of each alternative with respect to each criterion.

4.2 Individual Analysis of Alternatives

This section provides a detailed analysis of each alternative identified for Landfill 4 relative to the first seven of the nine evaluation criteria. Table 4-2 summarizes the individual analysis for each alternative. Tables 4-3 through 4-6 identify the applicable or relevant and appropriate ARARs for Landfill 4 and present a determination if each alternative satisfies the particular ARAR.

4.2.1 Alternative 1 – No Action

Alternative 1 is the no-action alternative, which includes no remedial elements. Long-term monitoring is not included in this option.

4.2.1.1 Overall Protection of Human Health and Environment

The no-action alternative would not be protective to human health and the environment because it does not satisfy the RAOs identified for the site to limit the potential for ponding of storm water on the landfill surface, reduce the potential for erosion due to wind and water, limit the potential for contact with landfill materials and groundwater that may create a physical hazard to humans, and determine if restoration of groundwater is required at the site.

4.2.1.2 Compliance with ARARs

Landfill 4 was closed prior to current landfill construction practices and regulations. Because Landfill 4 is considered “grandfathered,” the landfill is not required to fully comply with current site and construction criteria under federal rules or WSWMRR. However, potential leaching of landfill contaminants may cause or contribute to groundwater contamination in excess of MCLs or WWQRR, which are relevant groundwater remediation goals for Landfill 4.

4.2.1.3 Long-Term Effectiveness

The no-action alternative does not actively remove or treat contamination. Therefore, the potential exists that future risks might increase due to erosion of cover soils exposing landfill wastes and/or increased infiltration into the landfill due to ponding of storm water. The lack of institutional controls would not control future use of the site.

4.2.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The no-action alternative will not reduce the toxicity, mobility, or volume of contaminants associated with Landfill 4, although these characteristics may be reduced by biodegradation and attenuation mechanisms, such as adsorption and dispersion.

4.2.1.5 Short-Term Effectiveness

Because no remedial actions are taken, there is no additional potential for short-term exposure to the community or construction workers. There are no ecological impacts associated with implementation of this alternative.

4.2.1.6 Implementability

The no-action alternative is easily implemented. No special technical or administrative challenges are associated with no action.

4.2.1.7 Cost

The no-action alternative will have no capital or long-term inspection and monitoring costs associated with its implementation.

4.2.2 Alternative 2 – Institutional Controls

Alternative 2 is institutional controls, which would limit access and future development at Landfill 4.

4.2.2.1 Overall Protection of Human Health and Environment

Institutional controls would partially satisfy RAOs by administratively limiting access to landfill materials and groundwater that may create a physical hazard to humans and restricting future land use of the area. However, institutional controls alone would not limit the potential for storm water to pond on the landfill surface, reduce the erosion potential from wind and water, or determine if restoration of groundwater is required at the site.

4.2.2.2 Compliance with ARARs

Institutional Controls do not fully comply with relevant and appropriate requirements of the WSWRR (see Table 4-6) for erosion control.

4.2.2.3 Long-Term Effectiveness

Institutional controls alone will not actively remove or treat contamination. Therefore, the potential exists that future risks might increase due to erosion of cover soils exposing landfill wastes and/or increased infiltration into the landfill. Institutional controls would restrict future access to contaminants present in soils, waste, and groundwater at Landfill 4.

4.2.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Institutional controls will not reduce the toxicity, mobility, or volume of contaminants associated with Landfill 4, although these characteristics may be reduced by biodegradation and attenuation mechanisms, such as adsorption to the soil matrix.

4.2.2.5 Short-Term Effectiveness

Because no actions are taken, there is no additional potential for short-term exposure to the community. Institutional controls will ensure that workers will conduct future activities at Landfill 4 using proper site controls and personal protective equipment (PPE). There are no ecological impacts associated with implementation of institutional controls.

4.2.2.6 Implementability

Institutional controls are easily implemented. No special technical or administrative challenges are associated with implementation.

4.2.2.7 Cost

The estimated costs for implementation of institutional controls are \$80,000 in capital cost and \$60,000 for semi-annual inspections for 30 years following implementation of the remedy. The NPV for this alternative is \$110,000 using a 5.0 percent discount factor. A 5.0 percent discount factor was used based on the status of F.E. Warren AFB as a non-EPA Federal Lead. Appendix C presents the cost estimate summary for this alternative.

4.2.3 Alternative 3 – Localized Site Improvements

This alternative consists of addressing localized areas of Landfill 4 which do not satisfy the RAOs identified in Section 2.2, establishing institutional controls, and implementing a long-term monitoring program. Site improvements will consist of surface controls to establish positive drainage patterns across the landfill, excavation and removal activities, waste consolidation, site restoration, and institutional controls.

4.2.3.1 Overall Protection of Human Health and Environment

Alternative 3 would be protective to human health and the environment because it satisfies the RAOs identified for the site to 1) limit the potential for ponding of storm water on the surface of the landfill; 2) reduce the potential for erosion from wind and water; 3) limit the potential for contact with landfill materials and groundwater that may create a physical hazard to humans; and 4) confirm if restoration of groundwater is required at the site.

Establishing positive drainage across the site will reduce the potential for infiltration into the landfill. The areas that pond storm water will be filled with cover soil and/or regraded to match the existing cover around the depression(s) and follow the existing surface grades and drainage patterns, which range from one to five percent across the landfill. The established and re-vegetated surface areas will have native deep-rooted grasses, which will serve to stabilize the existing cover and limit the potential for erosion due to wind and water. Excavation and removal activities, waste consolidation, site restoration, and institutional controls will limit the potential for exposure to landfill materials that create a physical hazard to humans. The inspection and monitoring program will include site inspections to evaluate if the landfill surface has stabilized, and groundwater and surface water monitoring to further evaluate adverse impacts, if any, attributed to landfill wastes.

Because the findings of the human health and ecological risk assessments concluded that no unacceptable human health or ecological risks were associated with the existing landfill configuration, and that the existing cover soil is generally greater than 2 feet thick, there was not a risk-based need to place additional cover soil over areas of the landfill to further reduce exposure to buried solid wastes.

4.2.3.2 Compliance with ARARs

This alternative will comply with the applicable contaminant-specific, action-specific, and location-specific ARARs listed in Tables 4-3 to 4-5. This alternative will also meet the relevant and appropriate requirements of the WSWMRR listed on Table 4-6.

4.2.3.3 Long-Term Effectiveness

Alternative 3 would decrease the future potential for erosion of cover soils exposing landfill wastes and/or increased infiltration into the landfill due to storm water ponding on the landfill surface. Institutional controls would administratively limit future contact with landfill materials and groundwater that may create a physical hazard to humans.

Site inspections would assess the long-term stability of the landfill and address deficiencies when they occur, such as ponding water. Groundwater and surface water monitoring would confirm if the landfill is adversely impacting groundwater quality and monitor the long-term effectiveness of the alternative to be protective of groundwater.

4.2.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Contaminant toxicity will be reduced by removing areas containing waste that could potentially degrade or erode in the future. These areas are identified on Figure 3-1 as buried solid waste. Contaminant mobility (due to infiltration into the landfill generating leachate) will be reduced by limiting ponding of storm water that could infiltrate into the landfill. Contaminant mobility due to wind and water erosion will be reduced by removing surficial

debris from the site and/or consolidating landfill debris under cover soils. Surficial concrete debris would also be removed from the floodplain under this alternative. Contaminant mobility due to buried solid waste in contact with groundwater will not be reduced by this alternative because the wastes are left in place.

4.2.3.5 Short-Term Effectiveness

The short-term effects as a result of implementing localized site improvements are evaluated below:

Protection of the Community. Implementation of localized site improvements will have minimal impact on the community. Field operations will be generally within the site boundary with controlled access, thereby limiting exposure risk to military or civilian personnel working on Base. Potential receptors include security personnel stationed at Gate 2 and vehicular traffic along Missile Drive.

The nearest on-Base residential area is Carlin Heights, located approximately 2,000 feet southwest of Landfill 4. The nearest off-Base residential areas are immediately east of (I-25, approximately 0.5 miles from Landfill 4, and the Nob Hill subdivision, approximately 1,500 feet southwest of Landfill 4.

The potential short-term impacts of implementing this alternative will be related to fugitive dust emissions from grading, excavation, and filling activities, and the increased truck traffic required to haul imported borrow soils and transport excavated wastes offsite. Noise associated with the construction equipment and increased traffic may be a temporary nuisance, but should not be at unacceptable levels. Fugitive dust and traffic control measures will be implemented to reduce impacts on the community.

Protection of Workers. The majority of the work will require the use of heavy equipment. Engineering controls, monitoring, and PPE will be used during implementation to reduce worker exposure. Primary risks to workers include fugitive dust, physical hazards, and chemical exposure to a lesser extent. In addition, the potential for exposure to unexploded ordnance (UXO) exists during intrusive activities. These potential risks can be mitigated by using Occupational Safety and Health Administration (OSHA)-trained workers and implementing appropriate controls that are typical for CERCLA landfill sites. Dust suppression will be implemented to reduce inhalation exposures. Trained UXO personnel will provide construction-related support/oversight during intrusive operations.

Short-Term Environmental Impacts. Short-term environmental impacts include fugitive dust emissions during construction and temporary loss of habitat until the re-vegetated areas are established. Engineering controls and best management practices (BMPs) will be used to reduce such impacts.

Time Until Response Objectives are Achieved. It is anticipated that this alternative may take approximately 1 to 2 months to implement the earthwork activities. Assuming RAOs are achieved when the vegetation is established, it is anticipated that the RAOs will be met within 2 years following revegetation.

4.2.3.6 Implementability

Technical Feasibility. The alternative is technically feasible. The majority of the work will be completed using standard heavy construction equipment. Material required to implement the alternative, such as imported soil, should be available in close proximity to the Base. Engineering design efforts necessary to complete the plans and specifications to implement this alternative are consistent with general civil engineering practice standards. There will be some uncertainties in material and waste handling volumes, but the flexibility of utilizing excess onsite soils where greater than 30 inches of cover soil is presently available is one example where this alternative can achieve the RAOs while managing technical uncertainties.

Administrative Feasibility. The alternative is administratively feasible. Although permits are not required for remedial actions at CERCLA sites (Section 121[e]), the substantive requirements of applicable regulations will be followed. Coordination will be required with the EPA and WDEQ to ensure compliance with substantive requirements of the Clean Water Act, Clean Air Act, and NPDES storm water regulations. The USAF may also need to consult with the U.S. Fish and Wildlife Service (USFWS) to ensure that proper mitigation measures are taken to protect the riparian habitat along Crow Creek.

No easements or right-of-way acquisitions are required on USAF-owned and controlled property; however, some electrical and water utilities are present onsite. If excavation activities should encroach on utility easements, the utilities would be isolated to complete the field operations. No adjacent or adjoining properties will be impacted by implementation of this alternative.

Availability of Services and Materials. Equipment required to complete this alternative is common heavy construction earth-moving and material-handling machinery. Materials, such as borrow soil, should be readily available within proximity of the Base.

State and Community Acceptance. State and community acceptance will be determined based on comments received during the public comment period. A 30-day public comment period will follow submittal of the Final FS to the regulatory agencies. A responsiveness summary will be prepared as part of the Record of Decision (ROD) for Landfill 4 to address all significant public comments received and to discuss impacts on the FS and proposed remedy for Landfill 4.

4.2.3.7 Cost

The estimated costs for implementation of this alternative are \$1,950,000 in capital cost and \$5,118,500 in inspection and monitoring costs for 30 years following implementation of the remedy. The NPV for this alternative is \$4,900,000 using a 5.0 percent discount factor. A 5.0 percent discount factor was used based on the status of F.E. Warren AFB as a non-EPA Federal Lead. Appendix C presents the cost estimate summary for this alternative.

4.2.4 Alternative 4 – Engineered Containment System

Alternative 4 consists of installing a landfill cap over Landfill 4. Waste consolidation, cap site grading, cap construction, and revegetation are components of this alternative.

4.2.4.1 Overall Protection of Human Health and Environment

Alternative 4 achieves protection by further “containing” the landfill wastes, stabilizing the landfill surface, and minimizing infiltration into the landfill. The landfill cap acts as an infiltration (or low permeability) barrier to restrict infiltration into the landfill. The cap surface will be stabilized with shallow-rooted grasses to reduce wind and erosion potential. The landfill cap will be graded at a minimum 3 percent slope to reduce the potential for future maintenance due to settlement and/or ponding of storm water

Site inspections would be implemented for a period of 30 years to evaluate if the landfill surface has stabilized, and five years groundwater and surface water monitoring will determine if adverse impacts, if any, are related to landfill wastes. Institutional controls will be implemented to restrict future land and groundwater use in the area.

4.2.4.2 Compliance with ARARs

This alternative will comply with the applicable contaminant-specific, action-specific, and location-specific ARARs listed in Tables 4-3 to 4-5. This alternative will also meet the relevant and appropriate requirements of the WSWMRR listed on Table 4-6.

4.2.4.3 Long-Term Effectiveness

Alternative 4 would be effective at reducing future risk by establishing a cap specifically designed to contain the landfill wastes. Institutional controls would further restrict future access to landfill materials that create a physical hazard to humans. The site inspections would assess the long-term stability of the landfill and address deficiencies when they occur, such as ponding of storm water and erosion due to wind and water. Groundwater and surface water monitoring would confirm if the landfill is adversely impacting groundwater and assess the long-term effectiveness of the remedy.

4.2.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The RI suggests that Landfill 4 wastes are non-hazardous. This alternative would not reduce contaminant toxicity or volume by treatment. Capping is an effective containment method to minimize the potential for infiltration into a landfill and stabilize the surface of the landfill, and thereby achieve a reduction in contaminant mobility.

4.2.4.5 Short-Term Effectiveness

The short-term effects as a result of constructing a landfill cap are evaluated below:

Protection of the Community. Implementation of a landfill cap will have moderate impact on the community, due primarily to the large volumes of soil to be hauled to the site. Field operations will be generally within the site boundary with controlled access, thereby limiting exposure risk to military or civilian personnel working on Base. Potential receptors include security personnel stationed at Gate 2 and vehicular traffic along Missile Drive.

The nearest on-Base residential area is Carlin Heights, located approximately 2,000 feet southwest of Landfill 4. The nearest off-Base residential areas are immediately east of I-25, approximately 0.5 miles from Landfill 4, and the Nob Hill subdivision, approximately 1,500 feet southwest of Landfill 4.

The potential short-term impacts of implementing this alternative will be related to fugitive dust emissions from earthwork activities, such as grading, excavation, and filling, and the increased truck traffic required to haul imported borrow soils and transport excavated wastes on-site. Noise associated with the construction equipment and increased traffic may be a nuisance, but should not be at unacceptable levels. Fugitive dust and traffic control measures will be implemented to reduce impacts on the community.

Protection of Workers. The majority of the work will require the use of heavy equipment. Engineering controls, monitoring, and PPE will be used during implementation to reduce worker exposure. Primary risks to workers include fugitive dust, physical hazards, and chemical exposure to a lesser extent. In addition, the potential for exposure to UXO exists during intrusive activities. These potential risks can be mitigated by using OSHA-trained workers and implementing appropriate controls that are typical for CERCLA landfill sites. Dust suppression will be implemented to reduce inhalation exposures. Trained UXO personnel will provide construction-related support/oversight during intrusive operations.

Short-Term Environmental Impacts. Short-term environmental impacts include fugitive dust emissions during construction and temporary loss of habitat until the re-vegetated areas are established. Engineering controls and BMPs will be used to reduce such impacts.

Because shallow-rooted vegetation is required for the landfill cap, existing trees and mature vegetation will be cleared from the landfill cap area. As a result, the ecological use of the area may be changed.

Time Until Response Objectives are Achieved. It is anticipated that this alternative may take approximately 3 to 6 months to implement the earthwork activities. Assuming RAOs are achieved when the vegetation is established, it is anticipated that the RAOs will be met within 2 years following re-vegetation.

4.2.4.6 Implementability

Technical Feasibility. This alternative is technically feasible. The majority of the work will be completed using standard heavy construction equipment. Material required to implement the alternative, such as imported soil, should be available in close proximity to the Base. However, the relatively large volume (as compared to Alternative 3) of imported soils required for constructing the landfill cap may require additional effort to locate acceptable borrow source(s). Engineering design efforts necessary to complete the plans and specifications to implement this alternative are consistent with general civil engineering practice standards.

Administrative Feasibility. The alternative is administratively feasible. Although permits are not required for remedial actions at CERCLA sites (Section 121[e]), the substantive requirements of applicable regulations will be followed. Coordination will be required with the EPA and WDEQ to ensure compliance with substantive requirements of the Clean Water Act, Clean Air Act, and NPDES storm water regulations. The USAF may also need to consult with the USFWS to ensure that proper mitigation measures are taken to protect the riparian habitat along Crow Creek.

No easements or right-of-way acquisitions are required on USAF-owned and controlled property; however, some electrical and water utilities are present onsite. If excavation

activities should encroach on utility easements, the utilities would be isolated to complete the field operations. No adjacent or adjoining properties will be impacted by implementation of this alternative.

Availability of Services and Materials. Equipment required to complete this alternative is common heavy construction earth-moving and material-handling machinery. Materials, such as borrow soil, should be readily available within proximity of the Base.

State and Community Acceptance. State and community acceptance will be determined based on comments received during the public comment period. A 30-day public comment period will follow submittal of the Final FS to the regulatory agencies. A responsiveness summary will be prepared as part of the ROD for Landfill 4 to address all significant public comments received and to discuss impacts on the FS and proposed remedy for Landfill 4.

4.2.4.7 Cost

The estimated costs for implementation of this alternative are \$4,730,000 in capital cost and \$5,151,000 in O&M costs for 30 years of inspections and monitoring. The NPV for this alternative is \$7,700,000 using a 5.0 percent discount factor. A 5.0 percent discount factor was used based on the status of F.E. Warren AFB as a non-EPA Federal lead. Appendix C presents the cost estimate summary for this alternative.

4.2.5 Alternative 5 – Full Excavation and Disposal

Alternative 5 consists of excavating Landfill 4 waste materials (and intermixed soils) and transporting the waste materials to a disposal facility that can accept CERCLA wastes. For the purpose of this FS, the waste is considered to be non-hazardous and could be disposed at the North Weld Landfill near Ault, Colorado, approximately 40 miles south of the Base. However, if available space and other considerations allow, the on-Base WCA could also be used for some or all of the excavated waste.

4.2.5.1 Overall Protection of Human Health and Environment

This alternative is protective of human health and the environment by removing the landfill waste and restoring the site. By removing the landfill waste from the site, the need to minimize ponding of storm water and reduce the potential for wind and water erosion is no longer relevant. The alternative will minimize contact with landfill materials because they are physically removed from the site.

4.2.5.2 Compliance with ARARs

This alternative will comply with the applicable contaminant-specific, action-specific, and location-specific ARARs listed in Tables 4-3 to 4-5. This alternative will also meet the relevant and appropriate requirements of the WSWMRR listed on Table 4-6.

4.2.5.3 Long-Term Effectiveness

Alternative 5 will achieve long-term effectiveness by removing the landfill wastes and disposing them in an approved landfill facility that would isolate the contaminants from any contact with potential receptors. No long-term adverse impacts are anticipated for this alternative.

The site inspections would assess the site conditions until the site has stabilized and the vegetation is established. Groundwater and surface water monitoring would determine if the excavation activities inadvertently caused contaminants in the waste to be mobilized to groundwater and confirm that iron and manganese concentrations in groundwater are background. Institutional controls would restrict access to groundwater.

4.2.5.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The RI suggests that Landfill 4 wastes are non-hazardous. The mobility of the contaminants at the site will be reduced by disposing all of the landfill wastes in an approved landfill facility. The landfill facility reduces contaminant mobility by containment, including bottom-liner systems and landfill caps, similar to Alternative 4. The toxicity and volume of landfill wastes would remain unchanged.

4.2.5.5 Short-Term Effectiveness

The short-term effects as a result of constructing a landfill cap are evaluated below:

Protection of the Community. Implementation of Alternative 5 will have a moderate impact on the community. Although construction activities will be generally within the site boundary with controlled access, the duration of the excavation and removal activities, along with the hauling of wastes from the site, will increase the possibility of impacts to the military and civilian personnel working at or visiting the Base. Potential receptors include security personnel stationed at Gate 2 and vehicular traffic along Missile Drive.

The nearest on-Base residential area is Carlin Heights, located approximately 2,000 feet southwest of Landfill 4. The nearest off-Base residential areas are immediately east of I-25, approximately 0.5 miles from Landfill 4, and the Nob Hill subdivision, approximately 1,500 feet southwest of Landfill 4.

The potential short-term impacts of implementing this alternative will include fugitive dust emissions from earthwork activities, such as grading, excavation, and filling, and the increased truck traffic required to haul imported borrow soils and transport excavated wastes offsite. Noise associated with the construction equipment and increased traffic may be a nuisance, but should not be at unacceptable levels. Fugitive dust and traffic control measures will be implemented to reduce impacts on the community.

Protection of Workers. The majority of the work will require the use of heavy equipment. Engineering controls, monitoring, and PPE will be used during implementation to reduce worker exposure. Primary risks to workers include fugitive dust, physical hazards, and chemical exposure to a lesser extent. In addition, the potential for exposure to UXO exists during intrusive activities. These potential risks can be mitigated by using OSHA-trained workers and implementing appropriate controls that are typical for CERCLA landfill sites. Dust suppression will be implemented to reduce inhalation exposures. Trained UXO personnel will provide construction-related support/oversight during intrusive operations.

Short-Term Environmental Impacts. Short-term environmental impacts include fugitive dust emissions during construction and temporary loss of habitat until the revegetated areas are established. Engineering controls and BMPs will be used to reduce such impacts.

Because the excavation and removal activities will encompass the entire landfill area, existing trees and mature vegetation will be damaged and/or destroyed during implementation. As a result, the ecological use of the area will be impaired until the site is revegetated and the vegetation is established.

Time Until Response Objectives are Achieved. It is anticipated that this alternative may take approximately 6 to 12 months to implement. Assuming RAOs are achieved when the vegetation is established, it is anticipated that the RAOs will be met within 2 years following revegetation.

4.2.5.6 Implementability

Technical Feasibility. This alternative is technically feasible. The majority of the work will be completed using standard heavy construction equipment. However, the uncertainties in material handling and segregation capabilities may have a significant impact on project cost. As mentioned in Section 2, segregation of clean soil and waste is limited to the means and methods of the contractor, which can greatly impact the material handling and disposal estimates. The rate at which the contractor may proceed can also be limited by the level of UXO construction support required during excavation and the rate at which the wastes can be transported to an offsite disposal facility.

Administrative Feasibility. The alternative is administratively feasible. Although permits are not required for remedial actions at CERCLA sites (Section 121[e]), the substantive requirements of applicable regulations will be followed. Coordination will be required with the EPA and WDEQ to ensure compliance with substantive requirements of the Clean Water Act, Clean Air Act, and NPDES storm water regulations. The USAF may also need to consult with the USFWS to ensure that proper mitigation measures are taken to protect the riparian habitat along Crow Creek.

No easements or right-of-way acquisitions are required on USAF-owned and controlled property; however some electrical and water utilities are present on site. If excavation activities should encroach on utility easements, the utilities would be isolated to complete the field operations. No adjacent or adjoining properties will be impacted by implementation of this alternative.

Availability of Services and Materials. Equipment required to complete this alternative is common heavy construction earth-moving and material-handling machinery. Because the existing site cover soil would be segregated and reused to reestablish the site after the wastes are excavated, offsite borrow soils will likely not be required.

State and Community Acceptance. State and community acceptance will be determined based on comments received during the public comment period. A 30-day public comment period will follow submittal of the Final FS to the regulatory agencies. A responsiveness summary will be prepared as part of the Record of Decision (ROD) for Landfill 4 to address all significant public comments received and to discuss impacts on the FS and proposed remedy for Landfill 4.

4.2.5.7 Cost

The estimated costs for implementation of this alternative are \$8,200,000 in capital cost and \$3,006,000 in O&M costs for 30 years of inspections and monitoring. The NPV for this

alternative is \$9,900,000 using a 5.0 percent discount factor. A 5.0 percent discount factor was used based on the status of F.E. Warren AFB as a non-EPA Federal lead. Appendix C presents the cost estimate summary for this alternative.

4.3 Comparative Analysis of Alternatives

In the following sections, the alternatives are evaluated in relation to one another for each evaluation criterion. The purpose of the comparative analysis is to identify the relative advantages and disadvantages of each alternative. Table 4-7 summarizes the comparative analyses of each alternative.

4.3.1 Overall Protection of Human Health and Environment

Alternative 3 (Localized Actions), Alternative 4 (Engineered Containment System), and Alternative 5 (Excavation and Removal) satisfy the RAOs and are protective of human health and the environment. Alternative 1 (No Action) does not meet this threshold criterion because it does not meet any of the RAOs. Alternative 2 (Institutional Controls) does not meet this threshold criterion because it would not limit the potential for storm water to pond on the landfill surface or further reduce the potential for erosion from wind or water. Because Alternatives 1 and 2 do not meet this threshold criterion, it is not necessary to compare them with other alternatives as part of this comparative analysis.

Alternative 5 is protective by removing the landfill waste from the site and disposing of it at an approved landfill facility. Alternative 4 is protective by containing the landfill onsite and provides an additional measure of protection by installing a landfill cap specifically designed to minimize infiltration into the landfill. Alternative 3 meets this threshold criterion by addressing only those areas of the landfill where corrective measures are required to limit ponding of storm water, reduce the potential for erosion in areas lacking vegetation, and removing landfill materials that create a physical hazard to humans. Each of these alternatives would incorporate institutional controls to further limit the potential for contact with landfill materials that create a physical hazard to humans. Inspection and monitoring programs would be included for Alternatives 3, 4, and 5 to monitor the site stability, address RAO 4, and monitor the long-term effectiveness of the remedy.

4.3.2 Compliance with ARARs

Alternatives 3, 4, and 5 all comply with the applicable contaminant-specific, action-specific, and location specific ARARs listed in Tables 4-3 to 4-5. Each of these alternatives will also meet the relevant and appropriate requirements of the WSWMRR listed on Table 4-6.

4.3.3 Long-Term Effectiveness and Permanence

Alternative 5 affords the highest degree of long-term effectiveness and permanence by physically removing landfill wastes from the site. Alternatives 3 and 4 are generally similar in being effective long-term onsite remedial alternatives. From a site stability perspective (i.e., limiting ponding of storm water, reducing erosion potential), Alternative 3 may be more effective because the loss of mature vegetation would be limited and only localized areas would be addressed. Alternative 4 would require that the existing mature vegetation be destroyed and replaced with shallow-rooted grasses. Alternative 4 would also require

that a significant amount of regrading and/or placement of fill material occur, which may create additional settlement across the site and require a longer period of site inspections until the site stabilizes. Each of these alternatives would implement similar institutional controls and inspection and monitoring programs.

4.3.4 Reduction in Toxicity, Mobility, or Volume through Treatment

Alternatives 3, 4, and 5 do not reduce toxicity, mobility, or volume through treatment. However, these alternatives are intended to reduce contaminant mobility through containment. Alternative 5 is the most effective because the wastes would be disposed at an offsite landfill facility that would have a bottom-liner system in addition to a landfill cap. Alternative 4 may be more effective than Alternative 3 in reducing contaminant mobility because an infiltration barrier would be installed, whereas Alternative 3 relies more on the water storage capacity of the cover soil, and evapotranspiration processes.

4.3.5 Short-Term Effectiveness

Alternative 3 would have the least short-term impact on the community, workers, and the environment. Construction activities would be limited to localized areas around the landfill and only identified unburned wastes would be exposed while excavating and loading trucks for offsite disposal. The reduced amount of hauling of borrow soil and wastes would limit the amount of truck traffic required to complete the alternative. Alternative 3 could also be completed within a short period (1 to 2 months).

Alternative 4 would have an increased short-term impact on the community, workers, and the environment. Alternative 4 would require disturbing the entire site, resulting in increased potential for fugitive dust emissions. There would also be increased truck traffic required to transport up to 172,000 cy of borrow soils to construct the landfill cap. Alternative 4 could be completed within 3 to 6 months.

Alternative 5 would have the greatest short-term impact on the community, workers, and the environment. Alternative 5 would also require disturbing the entire site, and handling the greatest amount of landfill wastes, resulting in an increased exposure to contaminants. There would also be increased truck traffic to transport 120,000 cy of waste, concrete, and demolition debris to an offsite facility. Alternative 5 could be completed within 6 to 12 months.

4.3.6 Implementability

Alternatives 3, 4, and 5 can be technically and administratively implemented. However, there are important technical uncertainties that differentiate the ability to effectively implement each alternative. Alternative 3 is the most efficient to implement with the fewest uncertainties (such as obtaining borrow soils) that could impact the level of effort and cost to complete. Alternative 4 could be implemented in a fashion similar to Alternative 3, but the level of effort is increased to complete the work and there would be additional uncertainty in obtaining borrow soils for construction of the cap in close proximity to the landfill. Alternative 5 is the least implementable of the alternatives because of the increased level of effort required and the uncertainties in the amount of waste that would ultimately be disposed at an approved landfill facility.

4.3.7 Cost

The costs for each alternative are summarized below. Alternative 3 would have the lowest capital cost, approximately one-third of the cost for Alternative 4 and one-fourth of the cost for Alternative 5. The total O&M (i.e., inspection and monitoring) costs for Alternatives 3 and 4 are similar, except that additional site inspections would be required for Alternative 4 until the landfill cap stabilizes. The O&M costs for Alternative 5 are similar to the Alternatives 3 and 4, except that the number of monitoring well locations was reduced to assess the condition of groundwater and confirm that the vegetation is established after the waste is removed.

Alternative	Capital Cost	Total O&M Cost	Net Present Value (5.0% Discount Factor)
1. No Action	\$ 0	\$ 0	\$ 0
2. Institutional Controls	\$ 80,000	\$ 60,000	\$ 110,000
3. Localized Site Improvements	\$ 1,950,000	\$ 5,118,500	\$ 4,900,000
4. Engineered Landfill Cap	\$ 4,730,000	\$ 5,150,000	\$ 7,700,000
5. Excavation and Removal	\$ 8,200,000	\$ 3,006,000	\$ 9,900,000

4.3.8 Summary of Comparative Analysis

As summarized on Table 4-7, Alternatives 3, 4, and 5 all meet the threshold criterion and are effective in reducing future risks at Landfill 4. Alternative 3 is the most cost effective alternative that meets the RAOs and can be readily implemented onsite with low short-term impacts to workers, the community, and the environment.. Alternative 4 would have low to moderate short-term impacts to workers, the community, and the environment because of the amount of material handling required to construct the cap. Alternative 5 would have a moderate short-term impact to workers, the community, and the environment because of the volume of waste materials that would be managed, but would be the most effective long-term because wastes are removed from the site. However, the technical and cost uncertainties of implementing Alternative 5 provide an indication that an onsite remedy (Alternative 3 or 4) may be most appropriate given the low risk that the site currently poses to human health and the environment.

SECTION 5.0

References

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Table 2-1
Technology Screening for Landfill 4
Feasibility Study for Landfill 4

General Response Actions	Technology Type	Process Option	Description	Technical Implementability	Retained?
No action	None	No action	No institutional controls or remedial actions are implemented	Required by NCP to be carried through detailed analysis of alternatives	Yes
Institutional Controls	Land Use Controls	None	Restrict use of site. Digging permits reviewed by FEW.	Implementable	Yes
	Groundwater Restrictions	None	Restrict use of groundwater beneath site	Implementable	Yes
	Site Postings	None	Install signs indicating that access to the site is restricted	Implementable	Yes
In-situ remediation	Surface Controls	Grading	Reshaping topography to create positive drainage patterns across the site.	Implementable	Yes
		Revegetation	Seeding area with native vegetation for erosion control	Implementable	Yes
	Containment	Cover soils	Determination and placement of additional cover soil over areas of the landfill where settlement has occurred; placement of at least 30-inches of cover soil over areas where buried solid waste is exposed during implementation of remedial action	Implementable	Yes
		Engineered Cap	An engineered low permeability cap over landfill units that reduce infiltrations into the landfill	Implementable	Yes
Ex-situ remediation	Excavation	Mechanical Excavation	Use of mechanical excavation equipment to remove and load landfill wastes for disposal	Implementable	Yes
		Consolidation	Consolidation of excavated material from one spot to another in the landfill	Implementable	Yes
	Removal	Disposal	Transport and disposal of excavated materials to a RCRA permitted facility that can accept CERCLA waste	Implementable	Yes

Table 2-2
Process Option Evaluation for Landfill 4
Feasibility Study for Landfill 4

General Response Actions	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Issues/Comments	Retained?
No action	None.	No action.	No institutional controls or remedial actions are implemented	Low	High	Low	Does not meet RAOs. Required by NCP to be carried through detailed analysis of alternatives	Yes
Institutional Controls	Land Use Controls	None.	Restrict use of site. Digging permits reviewed by FEW.	Medium	High	Low	Provides incremental protection to human receptors. Does not directly address RAOs.	Yes
	Groundwater Restrictions	None.	Restrict use of groundwater beneath site	High	High	Low	Addresses potential risks identified to exposure to groundwater underlying or downgradient of the site	Yes
	Site Postings	None.	Install signs indicating that access to the site is restricted	Medium	High	Low	Posting signs restricting access to Landfill 4 would be a low-cost means to warn a potential trespasser as compared to security fencing.	Yes
In-situ remediation	Surface Controls	Grading	Reshaping topography to create positive drainage patterns across the site.	Medium	High	Low	Meets RAO to limit the potential for ponding of storm water on the landfill surface	Yes
		Revegetation	Seeding area with native vegetation for erosion control	Medium	High	Low	Meets RAO to reduce the potential for erosion from wind and water.	Yes
	Containment	Cover soils	Determination and placement of at additional cover soil over areas of the landfill where settlement has occurred. Placement of at least 30-inches of cover soil over areas where buried solid waste is exposed during implementation of remedial action.	Medium	Medium	Medium	Meets RAO to limit the potential for ponding of storm water on the landfill surface	Yes
		Engineered Cap	An engineered low permeability cap over landfill units that reduce infiltrations into the landfill	High	Medium	High	Meets RAOs by limiting the potential for ponding of storm water on the landfill surface and reduces the potential for erosion from wind and water.	Yes
Ex-Situ Remediation	Excavation	Mechanical Excavation	Use of mechanical excavation equipment to remove and load landfill wastes for disposal	High	Low	Medium	Meets RAOs by excavating wastes from the landfill.	Yes
		Consolidation	Consolidation of excavated material from one spot to another in the landfill.	Medium	Low	Medium	May potentially satisfy RAOs in conjunction with other process options.	Yes
	Removal	Disposal	Transport and disposal of excavated materials to a RCRA permitted facility that can accept CERCLA waste.	High	Low	High	Meets RAOs by disposing wastes at an approved landfill facility.	Yes

Table 4-1
Evaluation Criteria
Feasibility Study for Landfill 4

Criterion	Description
Threshold Criteria	
Overall Protection of Human Health and the Environment	The assessment against this criterion describes how the alternative, as a whole, achieves and maintains protection of human health and the environment.
Compliance with ARARs	The assessment against this criterion describes how the alternative will meet the ARARs which are applicable or relevant and appropriate to that alternative, or if a waiver is justified.
Balancing Criteria	
Long-term Effectiveness and Permanence	The assessment against this criterion evaluates the long-term effectiveness of alternatives in maintaining protection of human health and the environment after RAOs have been met.
Reduction of Toxicity, Mobility, and Volume through Treatment	The assessment against this criterion evaluates the anticipated performance of the specific treatment technologies an alternative may employ.
Short-term Effectiveness	The assessment against this criterion examines the effectiveness of alternatives in protecting human health and the environment during the construction and implementation of a remedy until response objectives have been met.
Implementability	This assessment evaluates the technical and administrative feasibility of alternatives and the availability of required goods and services.
Cost	This assessment evaluates the capital and operation and maintenance (O&M) costs of each alternative.
Other Criteria	
State (Support Agency) Acceptance	This assessment reflects the state's (or support agency's) apparent preferences among or concerns about alternatives assessed after the public comment period.
Community Acceptance	This assessment reflects the community's apparent preferences among or concerns about alternatives assessed after the public comment period.

Table 4-2
Detailed Analysis of Alternatives
Feasibility Study for Landfill 4

Criterion	Alternative 1 No Action	Alternative 2 Institutional Controls	Alternative 3 Localized Site Improvements	Alternative 4 Engineered Landfill Cap	Alternative 5 Excavation and Removal
Overall Protection of Human Health and the Environment	Does not address RAOs limit potential for storm water to pond on the landfill surface, reduce the potential for wind and water erosion, and limit the potential for contact with landfill materials and groundwater that create a physical hazard to humans. No groundwater or surface water monitoring proposed to address RAO 4.	Does not address RAOs limit potential for storm water to pond on the landfill surface, reduce the potential for wind and water erosion. No groundwater or surface water monitoring proposed to address RAO 4.	Addresses RAOs only where required at Landfill 4 to limit the potential for ponding on the landfill surface, reduce the potential for wind and water erosion, and limit the potential for contact with landfill materials that create a physical hazard to humans. Groundwater and surface water monitoring will address RAO 4.	Addresses RAOs by constructing a landfill cap over the wastes to “contain” the landfill materials. Groundwater and surface water monitoring will address RAO 4.	Eliminates the potential for landfill wastes to pose a future risk by removing the waste material from the site In additional to source removal activities, Groundwater and surface water monitoring will address RAO 4.
Compliance with ARARs	Will not comply with ARARs.	Will not comply with ARARs.	Will Comply with ARARS.	Will Comply with ARARS.	Will Comply with ARARS.
Long-Term Effectiveness and Permanence	Future risk would not be monitored. No long-term groundwater and surface water program monitoring would be implemented.	Future risk would be reduced by land use and groundwater use restrictions. No long-term groundwater and surface water monitoring program would be implemented.	Low residual risk. Improvements to localized areas minimize ponding of storm water and reduce erosion potential. Surfical concrete and demolition debris will be disposed of offsite (or consolidated onsite), to further minimize physical hazards at the site. Long-term monitoring would monitor the effectiveness of the alternative.	Low residual risk. Landfill cap would “contain” the landfill materials. Long-term monitoring would monitor the effectiveness of the alternative.	Minimal residual risk because wastes and waste contaminants are removed from the site. Long-term monitoring would monitor the effectiveness of the alternative.
Reduction of toxicity, mobility, or volume by treatment	Will not reduce toxicity, mobility, or volume of contaminants.	Will not reduce toxicity, mobility, or volume of contaminants.	Contaminant mobility reduced by limiting ponding of storm water and reducing infiltration.	Contaminant mobility reduced by capping site and minimizing infiltration.	Contaminant mobility reduced by disposing wastes at an offsite landfill.
Short Term Effectiveness	No short-term impacts to community, workers, or the environment.	No short-term impacts to community, workers, or the environment.	Minimal impacts to the community due to fugitive dust emissions and truck traffic. Minimal impacts to workers because intrusive activities are limited. Environmental impacts limited to areas disturbed during construction. Estimated construction time is 1 to 2 months.	Low to moderate impacts to the community due to fugitive dust emissions and increased truck traffic. Low to moderate impacts to workers because intrusive activities are more extensive than Alternative 3. Environmental impacts will include disturbing the entire footprint of Landfill 4 Estimated construction time is 3 to 6 months.	Greatest impacts to the community due to fugitive dust emissions, potential exposure to waste materials, and increased truck traffic. Moderate impacts to workers because intrusive activities will include handling all of the waste at Landfill 4. Environmental impacts will include disturbing the entire footprint of Landfill 4 Estimated construction time is 6 to 12 months.
Implementability	Readily Implementable.	Readily Implementable.	Readily implementable. Simplest alternative requiring construction to implement.	Implementable. Some technical uncertainties with availability of affordable borrow sources near the site.	Implementable. Some technical uncertainties in the amount of waste and soil that would ultimately be disposed.
Costs					
- Capital Cost	\$0	\$80,000	\$1,95,000	\$4,730,000	\$8,200,000
- O& M Cost	\$0	\$60,000	\$5,118,500 (over 30 years)	\$5,151,000 (over 30 years)	\$3,006,000 (over 30 years)
- Net Present Value of Alternative (5.0% discount factor)	\$0	\$110,000	\$4,900,000	\$7,700,000	\$9,900,000

TABLE 4-3

Analysis of Potential Chemical-Specific ARARs
Feasibility Study for Landfill 4

Standard, Requirement, Criterion, or Limitation	Citations	Description	Applicable or Relevant and Appropriate	Comments
Federal				
Safe Drinking Water Act [MCL]	42 USC Section 300 [40 CFR 141, 142, 143]	Establishes primary and secondary standards for drinking water quality to protect health and public welfare, including standards for metals, VOCs, and SVOCs.	No/Yes	Alternatives 1 and 2 – No groundwater monitoring proposed. Alternatives 2, 3, 4, & 5 – Groundwater monitoring will be completed to verify effectiveness of remedy to reduce impacts to groundwater. Note - The Secondary MCL for iron is 300 µg/L. The Secondary MCL for manganese is 50 µg/L. Secondary MCLs are generally not enforceable as ARARs. Upgradient concentrations of iron and manganese are greater than SMCLs.
State of Wyoming				
Wyoming Air Quality Standards and Regulations (Clean Air Act)	Chapter 1, Section 3 (40 CFR Part 50)	Establishes ambient air standards for particulate matter.	Yes/--	Alternatives 1 & 2 – Will not include remedial actions that will result in emissions. Alternatives 3, 4, & 5 – Best management practices will be implemented to minimize fugitive dust emissions to comply with applicable requirements. BMPs include tarping/covering of soils piles and wetting of soils.
	Chapter 2, Section 2 (40 CFR Part 50)	Establishes ambient air standards for particulate matter and other air pollutants.	Yes/--	Alternatives 1 & 2 – Will not include remedial actions that will result in emissions. Alternatives 3, 4, & 5 – Will utilize BMPs, such as tarping/covering of soil piles and wetting soil to limit the emission of fugitive dust.
Wyoming Water Quality Rules and Regulations (Surface Water) (Clean Water Act)	Chapter 1, Section 8 (40 CFR Part 302)	Requires that the level of quality of a surface water body be maintained consistently with the uses established on or after November 28, 1975, for that water body.	Yes/--	Alternatives 1, 2, 3 & 4 – Will not include remedial actions that will require dewatering. Alternatives 5 - Water generated from any dewatering activities will be analyzed and treated or disposed of in compliance with the Wyoming Water Quality Rules and Regulations, as well as the NPDES program. Note - Groundwater would require treatment for the following compounds if discharged to Crow Creek from dewatering operations (i.e. maximum concentrations of compounds in groundwater which exceed Chapter 1 standards for a Class 2AB stream): benzo(a)pyrene, aluminum, arsenic, chromium, iron, lead, manganese, and mercury.

TABLE 4-3

Analysis of Potential Chemical-Specific ARARs
Feasibility Study for Landfill 4

Standard, Requirement, Criterion, or Limitation	Citations	Description	Applicable or Relevant and Appropriate	Comments
	Chapter 1, Section 13 (40 CFR Part 131)	Prohibits the introduction of toxic materials, except those listed in Sections 21 (e) and (f) of these regulations, in concentrations or combinations which constitute pollution.	Yes/--	Alternatives 1, 2, 3 & 4 – Will not include remedial actions that will require dewatering. Alternative 5 - Water generated from any dewatering activities will be analyzed and treated or disposed of in compliance with the Wyoming Water Quality Rules and Regulations, as well as the NPDES program.
	Chapter 1, Section 18 (40 CFR Part 301)	Establishes human health protective concentration limits in Appendix B for specific contaminants.	Yes/--	Alternatives 1, 2, 3 & 4 – Will not include remedial actions that will require dewatering. Alternative 5 - Water generated from any dewatering activities will be analyzed and treated or disposed of in compliance with the Wyoming Water Quality Rules and Regulations, as well as the NPDES program.
Wyoming Water Quality Rules and Regulations (Surface Water) (Continued) (Clean Water Act)	Chapter 1, Section 21(a, c) (40 CFR Part 131)	Protection of aquatic life for ammonia and other pollutants.	Yes/--	Alternatives 1, 2, 3 & 4 – Will not include remedial actions that will require dewatering. Alternative 5 - Water generated from any dewatering activities will be analyzed and treated or disposed of in compliance with the Wyoming Water Quality Rules and Regulations, as well as the NPDES program.
	Chapter 18 (40 CFR Part 122, 125)	Requires NPDES Permitting for off-site discharges of storm water or waste water associated with certain industrial or construction activities.	Yes/--	Alternatives 1, 2, 3 & 4 – Will not include remedial actions that will require dewatering. Alternative 5 - Water generated from any dewatering activities will be analyzed and treated or disposed of in compliance with the Wyoming Water Quality Rules and Regulations, as well as the NPDES program.
Wyoming Water Quality Rules and Regulations (Groundwater) (Clean Water Act)	Chapter 8 (40 CFR Part 302)	Establishes ambient water quality standards for various chemical constituents and other parameters for the protection of groundwater.	Yes/--	Alternatives 1 and 2 – No groundwater monitoring proposed. Alternatives 2, 3, 4, & 5 – Groundwater monitoring will be completed to verify effectiveness of remedy to reduce impacts to groundwater. Note - The groundwater standards for iron and manganese in groundwater are 300 µg/L and 50 µg/L, respectively. These concentrations are the lower of the Class 1 (Domestic) and Class 2 (Agriculture) standards. The range of iron and manganese concentrations detected in groundwater at Landfill 4 are non-detect to 10,200 µg/L for iron, and 0.44 µg/L to 3,900 µg/L for manganese. Concentrations of iron and manganese in groundwater upgradient of Landfill 4 are greater than the groundwater standards.

TABLE 4-3

Analysis of Potential Chemical-Specific ARARs
Feasibility Study for Landfill 4

Standard, Requirement, Criterion, or Limitation	Citations	Description	Applicable or Relevant and Appropriate	Comments
Wyoming Solid Waste Management Rules and Regulations (RCRA)	Chapter 2 (Appendices A & B) (40 CFR Part 264)	Lists chemical compounds, analytical methods, and detection limits to be used for monitoring sanitary landfills.	No/No	Alternatives: ALL – The suitability of testing procedures shall be determined by the USAF in consultation with the WDEQ and the EPA.
Wyoming Hazardous Waste Rules and Regulations (RCRA)	Chapter 2 (40 CFR Part 261)	Identifies and lists hazardous waste	Yes/--	Alternatives: ALL – If hazardous waste is generated during remediation, these provision would apply. Provisions are applicable in identifying listed or characteristic hazardous waste subject to other substantive requirements.
	Chapter 13 (40 CFR Part 268)	Addresses Land Disposal Restrictions	Yes/--	Alternatives: ALL – If hazardous waste is generated during remediation, these provision would apply.

Notes:

An ARAR can not be both “applicable” and “relevant and appropriate” (either “Yes/--“ or “No/Yes”). If an ARAR is determined to be “applicable” the determination of “relevant and appropriate” is not needed (i.e. “Yes/--”) since the “applicable” determination already makes that requirement of environmental law an ARAR.

ARAR = Applicable or relevant and appropriate requirements
 CFR = Code of Federal Regulations
 W.S. = Wyoming statute

Corresponding Federal Citations

40 CFR Part 50	National Primary and Secondary Ambient Air Quality Standards	Establishes standards for ambient air quality to protect public health and welfare
40 CFR Part 302	Water Quality Standards and Effluent Limitations	Protection of intended uses of receiving waters
40 CFR Part 131	Water Quality Criteria	Sets water quality criteria based on toxicity to aquatic organisms and human health
40 CFR Part 301	Effluent Limitations	Technology based limitations for point source discharge to surface waters of conventional, non-conventional, and toxic pollutants
40 CFR Part 122, 125	National Pollutant Discharge Elimination System Permit Regulations	Establishes permitting requirements and criteria and standards for technology based treatments requirements for effluent discharge and storm water runoff.
40 CFR Part 264	RCRA Solid Waste Management Regulations, Subtitle D	Applicable to the management and disposal of non-hazardous wastes.
40 CFR Part 261	Identification and Listing of Hazardous Waste	Defines those solid wastes that are subject to regulations as hazardous waste under 40 CFR Parts 262-265 and Parts 124, 270, and 271.
40 CFR Part 268	Land Disposal Restrictions	Applicable to alternatives involving land disposal of hazardous waste and requires treatment to diminish a waste’s toxicity and/or minimize contaminant migration.

TABLE 4-4

Analysis of Potential Action-Specific ARARs

Feasibility Study for Landfill 4

Standard, Requirement, Criterion, or Limitation	Citations	Description	Applicable or Relevant and Appropriate	Comments
State of Wyoming				
Wyoming Air Quality Standards and Regulations (Clean Air Act)	Chapter 2, Section 2 (40 CFR Part 50)	Establishes requirements for the control of particulate emissions.	Yes/--	Alternatives 1 & 2 – Will not include remedial actions that will result in emissions. Alternatives 3, 4, & 5 – Best management practices will be implemented to minimize fugitive dust emissions to comply with the Clean Air Act. BMPs include tarping/covering of soils piles and wetting of soils.
	Chapter 2, Section 11 (40 CFR Part 50)	Establishes ambient air standards for odors.	Yes/--	Alternatives 1 & 2 – Will not include remedial actions that will result in odors. Alternatives 3, 4, & 5 – Unburned wastes will be excavated and disposed to eliminate gas producing decomposition of waste material. Excavations will be back-filled with clean material.
	Chapter 3, Section 3(f) (40 CFR Part 50)	Requires sources operating within the State of Wyoming to control fugitive dust.	Yes/--	Alternatives 1 & 2 – Will not include remedial actions that will result in emissions. Alternatives 3, 4, & 5 – Will utilize BMPs, such as tarping/covering of soil piles and wetting soil to limit the emission of fugitive dust.
Wyoming Hazardous Waste Management Rules and Regulations (RCRA)	Chapter 2 (40 CFR Part 261)	Identifies and lists hazardous waste.	Yes/--	Alternatives 1 and 2 – Will not result in excavation of material. Alternatives 3 and 4 – Hazardous waste could be generated as a result of these alternatives, however, the waste would remain within the Area of Concern and so would not require classification. Alternative 5 – If hazardous waste is generated by alternative 5, the waste will be characterized for off-site disposal at an appropriate facility.
	Chapter 13 (40 CFR Part 268)	Establishes land disposal restrictions (LDRs) for hazardous and non-hazardous waste.	Yes/--	Alternatives 1 & 2 – Will not result in excavation of material. Alternatives 3 and 4 – Hazardous waste could be generated as a result of these alternatives, however, the waste would remain within the Area of Concern and so would not require classification or off-site disposal. Alternative 5 – If hazardous waste is generated by alternative 5, the waste will be characterized for off-site disposal at an appropriate facility.

TABLE 4-4

Analysis of Potential Action-Specific ARARs

Feasibility Study for Landfill 4

Standard, Requirement, Criterion, or Limitation	Citations	Description	Applicable or Relevant and Appropriate	Comments
Wyoming Water Quality Rules and Regulations (Surface Water) (Clean Water Act)	Chapter 1, Section 10 (40 CFR Part 301)	Provides requirements for testing procedures of surface waters.	Yes/--	If testing of surface water is deemed necessary, the analysis will be conducted in accordance with 40 CFR 136. Testing procedures outlined in EPA Methods for Chemical Analysis of Water and Wastes Standard Methods for the Examination of Water and Wastewater will be used. Where standard methods of testing have not been established, the suitability of testing procedures shall be determined by USAF in consultation with WDEQ and EPA.
Wyoming Water Quality Rules and Regulations (Groundwater) (Clean Water Act)	Chapter 9, Sections 9-11 (40 CFR Part 302)	Provides requirements for the protection of groundwater through notification, monitoring, inspections, and recordkeeping.	Yes/--	Alternative 1 – Would not meet this ARAR as no institutional controls are proposed. Alternatives 2, 3, 4, & 5 – Institutional controls will ensure that groundwater is being protected or that releases are reported to the appropriate agency.
	Chapter 18 (40 CFR Parts 122 & 125)	Requires NPDES Permitting for off-site discharges of storm water or waste water associated with certain industrial or construction activities.	Yes/--	Alternatives 1, 2, 3 & 4 – Will not include remedial actions that will require dewatering. Alternative 5 - Water generated from any dewatering activities will be analyzed and treated or disposed of in compliance with the Wyoming Water Quality Rules and Regulations, as well as the NPDES program.
Wyoming Solid Waste Management Rules and Regulations (RCRA, Subtitle D)	Chapter 2, Section 6 (40 CFR Part 264)	Provides minimum standards for monitoring during landfill operation.	No/No	Not relevant and appropriate since Landfill 4 ceased operations no later than 1959.
	Chapter 2, Section 7(c) (40 CFR Part 264)	Requires the prevention of erosion and/or ponding of the final cover over closed sanitary landfills.	No/See Table 4-6	Post closure care requirements set forth in this chapter apply to permitted facilities. Since Landfill 4 ceased operations no later than 1959 and did not have a permit, post closure care requirements are not applicable.
	Chapter 2, Section 7(d) (40 CFR Part 264)	Provides specifications for the final cover over closed sanitary landfills.	No/No	Specifications are for closing or recently closed sanitary landfills, and do not account for settling and compaction that have occurred over a 45-year period or the nature and contents of Landfill 4.
	Chapter 2, Section 7(e) (40 CFR Part 264)	Requires re-vegetation to minimize wind and water erosion.	No/See Table 4-6	Post closure care requirements set forth in this chapter apply to permitted facilities. Since Landfill 4 ceased operations no later than 1959 and did not have a permit, post closure care requirements are not applicable.
	Chapter 2, Section 7(h) (40 CFR Part 264)	Requires access control during closure and re-vegetation of sanitary landfills.	No/See Table 4-6	Post closure care requirements set forth in this chapter apply to permitted facilities. Since Landfill 4 ceased operations no later than 1959 and did not have a permit, post closure care requirements are not applicable.

TABLE 4-4

Analysis of Potential Action-Specific ARARs

Feasibility Study for Landfill 4

Standard, Requirement, Criterion, or Limitation	Citations	Description	Applicable or Relevant and Appropriate	Comments
Wyoming Solid Waste Management Rules and Regulations (<i>Continued</i>) (RCRA, Subtitle D)	Chapter 2, Section 7(k) (40 CFR Part 264)	Requires maintenance and operation of environmental monitoring systems during closure and post-closure of sanitary landfills.	No/See Table 4-6	Post closure care requirements set forth in this chapter apply to permitted facilities. Since Landfill 4 ceased operations no later than 1959 and did not have a permit, post closure care requirements are not applicable.
	Chapter 2, Section 7(p) (40 CFR Part 264)	Requires that sanitary landfills be returned to post-closure land use(s) specified in the permit.	No/No	No permit was issued for Landfill 4 and so post-closure land uses were not specified. Institutional controls will be used to permit post-closure uses that are compatible with the chosen remedial alternative.
	Chapter 15 (All) (40 CFR Part 264)	Provides general provisions, definitions, and minimum construction standards for new and existing solid waste disposal and processing operations.	No/No	No permit was issued for Landfill 4. All construction, processing, and disposal was completed no later than 1959, predating the regulations. This chapter is cited by Chapter 2 of the Solid Waste Management Rules.
	Chapter 2, Section 3 (40 CFR Part 264)	Provides siting requirements for the installation of sanitary landfills.	No/No	No permit was issued for Landfill 4. All construction, processing, and disposal was conducted no later than 1959, predating the regulations. This chapter is cited by Chapter 2 of the Solid Waste Management Rules.
Wyoming Environmental Quality Act (RCRA)	Article 5, W.S. 35-11-516, 519 (40 CFR Parts 261, 262, 263)	Provides requirements for hazardous waste generators, transporters, and corrective action.	Yes/--	Alternative 1 – No excavation or long-term monitoring will be conducted as part of this alternative. Alternatives 2, 3, 4, & 5 - If hazardous waste is generated during excavation or long term monitoring, this chapter would apply. It is applicable as necessary to implement other substantive requirements.
Wyoming Hazardous Waste Rules and Regulations (RCRA)	Chapter 1 (40 CFR Part 261)	Provides overview and definitions	Yes/--	Alternative 1 – No generation of hazardous waste will occur as a result of this alternative. Alternatives 2, 3, 4, & 5 - If hazardous waste is generated during excavation or long term monitoring, this chapter would apply. It is applicable as necessary to implement other substantive requirements.
Wyoming Hazardous Waste Rules and Regulations (<i>Continued</i>) (RCRA)	Chapter 8 (40 CFR Part 262)	Sets standards for generators of hazardous waste	Yes/--	Alternative 1 – No generation of hazardous waste will occur as a result of this alternative. Alternatives 2, 3, 4, & 5 - If hazardous waste is generated during excavation or long term monitoring, this chapter would apply. It is applicable as necessary to implement other substantive requirements.
	Chapter 9 (40 CFR Part 263)	Sets standards for transporters of hazardous waste	Yes/--	Alternative 1 & 2 – No generation of hazardous waste will occur as a result of this alternative. Alternatives 3, 4, & 5 - If hazardous waste is generated during excavation or long term monitoring, this chapter would apply. It is applicable as necessary to implement other substantive requirements.

TABLE 4-4

Analysis of Potential Action-Specific ARARs
Feasibility Study for Landfill 4

Notes:

An ARAR can not be both “applicable” and “relevant and appropriate” (either “Yes/--“ or “No/Yes”). If an ARAR is determined to be “applicable” the determination of “relevant and appropriate” is not needed (i.e. “Yes/--”) since the “applicable” determination already makes that requirement of environmental law an ARAR.

ARAR = Applicable or relevant and appropriate requirements
CFR = Code of Federal Regulations
W.S. = Wyoming statute

Corresponding Federal Citations

40 CFR Part 50	National Primary and Secondary Ambient Air Quality Standards	Establishes standards for ambient air quality to protect public health and welfare
40 CFR Part 261	Identification and Listing of Hazardous Waste	Defines those solid wastes that are subject to regulations as hazardous waste under 40 CFR Parts 262-265 and Parts 124, 270, and 271.
40 CFR Part 268	Land Disposal Restrictions	Applicable to alternatives involving land disposal of hazardous waste and requires treatment to diminish a waste’s toxicity and/or minimize contaminant migration
40 CFR Part 301	Effluent Limitations	Technology based limitations for point source discharge to surface waters of conventional, non-conventional, and toxic pollutants
40 CFR Part 302	Water Quality Standards and Effluent Limitations	Protection of intended uses of receiving waters
40 CFR Part 122, 125	National Pollutant Discharge Elimination System Permit Regulations	Establishes permitting requirements and criteria and standards for technology based treatments requirements for effluent discharge and storm water runoff.
40 CFR Part 264	RCRA Solid Waste Management Regulations	Applicable to the management and disposal of non-hazardous wastes.
40 CFR Part 263	RCRA Solid Waste Management Regulations	Standards applicable to transporters of hazardous waste.
40 CFR Part 262	RCRA Solid Waste Management	Standards applicable to generators of hazardous waste.

TABLE 4-5

Potential Location-Specific ARARs

Feasibility Study for Landfill 4

Standard, Requirement, Criterion, or Limitation	Citations	Description	Applicable or Relevant and Appropriate	Comments
Federal				
National Environmental Policy Act & Environmental Impact Analysis Procedures	40 CFR Part 1500 & 32 CFR 989	Provides an environmental impact analysis process to help federal officials make decisions that are based on an understanding of environmental consequences.	Yes/--	Alternatives 1 and 2 – If this alternative is selected, then the remedial alternative has a finding of non-significant impact. Alternatives 3-5 – Use of any of these alternatives will improve the environment at Landfill 4.
Listing Endangered and Threatened Species and Designating Critical Habitat	50 CFR Part 17	Lists endangered and threatened species that must not be significantly impacted by remedial activities at Landfill 4.	Yes/--	The remediation area may potentially impact Critical Habitat for Preble's meadow jumping mouse (<i>Zapus hudsonius preblei</i>). The USAF will consult with Fish & Wildlife Service prior to implementation of remedial alternatives as per Section 7 of the Endangered Species Act.
Archaeological and Historic Preservation Act	16 USC Section 469	Establishes requirements for the evaluation and preservation of historical and archaeological data which may be destroyed through alteration of terrain as a result of a federal construction project.	Yes/--	Preservation of additional archaeological data may be necessary during implementation of waste removal activities. Findings of the cultural resources monitoring during the RI field activities concluded that additional archeological monitoring is not required at Landfill 4.
State of Wyoming				
Wyoming Water Quality Rules and Regulations	Chapter 1, Appendix A (40 CFR Part 131)	Provides classification for surface waters.	Yes/--	Remedial alternatives will meet the water quality standards required by the classification of Crow Creek. Crow Creek is a Class 2AB Stream.

Notes:

An ARAR can not be both “applicable” and “relevant and appropriate” (either “Yes/--“ or “No/Yes”). If an ARAR is determined to be “applicable” the determination of “relevant and appropriate” is not needed (i.e. “Yes/--”) since the “applicable” determination already makes that requirement of environmental law an ARAR.

ARAR = Applicable or relevant and appropriate requirements

CFR = Code of Federal Regulations

E.O. = Executive Order

Corresponding Federal Citations

40 CFR Part 131

Water Quality Criteria

Sets criteria for water quality based on toxicity to aquatic organisms and human health.

TABLE 4-6**Potential Relevant and Appropriate Requirements***Feasibility Study for Landfill 4*

Standard, Requirement, Criterion, or Limitation	Citations	Description	Relevant and Appropriate	Comments
State of Wyoming				
Wyoming Solid Waste Management Rules and Regulations (RCRA, Subtitle D)	Chapter 2, Section 7(c) (40 CFR Part 264)	Requires the prevention of erosion and/or ponding of the final cover over closed sanitary landfills.	Yes	Alternatives 1 & 2 – Pooling and erosion will not be controlled. Alternatives 3, 4, & 5 - Site regrading will create positive drainage to prevent ponding and erosion.
	Chapter 2, Section 7(e) (40 CFR Part 264)	Requires revegetation to minimize wind and water erosion.	Yes	Alternatives 1 & 2 – These alternatives do not require soil disturbance such that revegetation would be required. This requirement is not relevant and appropriate for these alternatives. Alternatives 3, 4, & 5 - Revegetation will be included within the Work Plan for one of these selected alternatives to minimize wind and water erosion.
	Chapter 2, Section 7(h) (40 CFR Part 264)	Requires access control during closure and revegetation of sanitary landfills.	Yes	Alternative 1 –The No Action Alternative does not provide institutional control to control access to the site. Alternatives 2, 3, 4, & 5 - Institutional controls, such as Land Use Controls, groundwater use restrictions, etc. are included to control access to the landfill for each of these alternatives.
	Chapter 2, Section 7(k) (40 CFR Part 264)	Requires maintenance and operation of environmental monitoring systems during closure and post-closure of sanitary landfills.	Yes	Alternative 1 & 2 –The No Action Alternative does not provide long-term monitoring. Alternatives 3, 4, & 5 - Groundwater will be monitored for a period of 30 years as part of these alternatives.

Notes:

An ARAR can not be both “applicable” and “relevant and appropriate” (either “Yes/--” or “No/Yes”). If an ARAR is determined to be “applicable” the determination of “relevant and appropriate” is not needed (i.e. “Yes/--”) since the “applicable” determination already makes that requirement of environmental law an ARAR.

ARAR = Applicable or relevant and appropriate requirements
 CFR = Code of Federal Regulations
 E.O. = Executive Order

Corresponding Federal Citations

40 CFR Part 264

RCRA Solid Waste Management Regulations

Applicable to the management and disposal of non-hazardous wastes.

Table 4-7

Comparative Analysis of Alternatives
Feasibility Study for Landfill 4

Criterion	Alternative 1 No Action	Alternative 2 Institutional Controls	Alternative 3 Localized Site Improvements	Alternative 4 Engineered Landfill Cap	Alternative 5 Excavation and Removal
Overall Protection of Human Health and the Environment	○ Will not comply with RAOs.	○ Will not comply with RAOs.	● Meets Threshold Criterion.	● Meets Threshold Criterion.	● Meets Threshold Criterion.
Compliance with ARARs	○ Not Compliant.	○ Not Compliant.	● Meets Threshold Criterion.	● Meets Threshold Criterion.	● Meets Threshold Criterion.
Long-Term Effectiveness and Permanence	- (see note 1)	- (see note 1)	⊙ Addresses RAOs and implements LTM.	⊙ Addresses RAOs and implements LTM.	● Removes wastes from site.
Reduction of toxicity, mobility, or volume by treatment	- (see note 1)	- (see note 1)	⊙ Contaminant mobility reduced by stabilizing site and reducing infiltration due to ponding water.	⊙ Contaminant mobility reduced by capping site and minimizing infiltration.	⊙ Contaminant mobility reduced by disposing wastes at an offsite landfill.
Short Term Effectiveness	- (see note 1)	- (see note 1)	● Low impact to workers, community, and environment.	⊙ Low to Moderate impacts to workers, community, and environment.	⊙ Moderate impacts to workers, community, and environment.
Implementability	- (see note 1)	- (see note 1)	● Few technical / administrative uncertainties. Simplest alternative to implement.	● Some technical uncertainties with availability of affordable borrow sources near the site.	⊙ Would require a significant amount of uncontaminated soil to be disposed with wastes.
Cost	- (see note 1)	- (see note 1)	● Lowest capital costs. O&M costs similar to Alternative 4.	⊙ High capital costs. O&M costs similar to Alternative 3.	⊙ High capital costs. Low O&M costs.

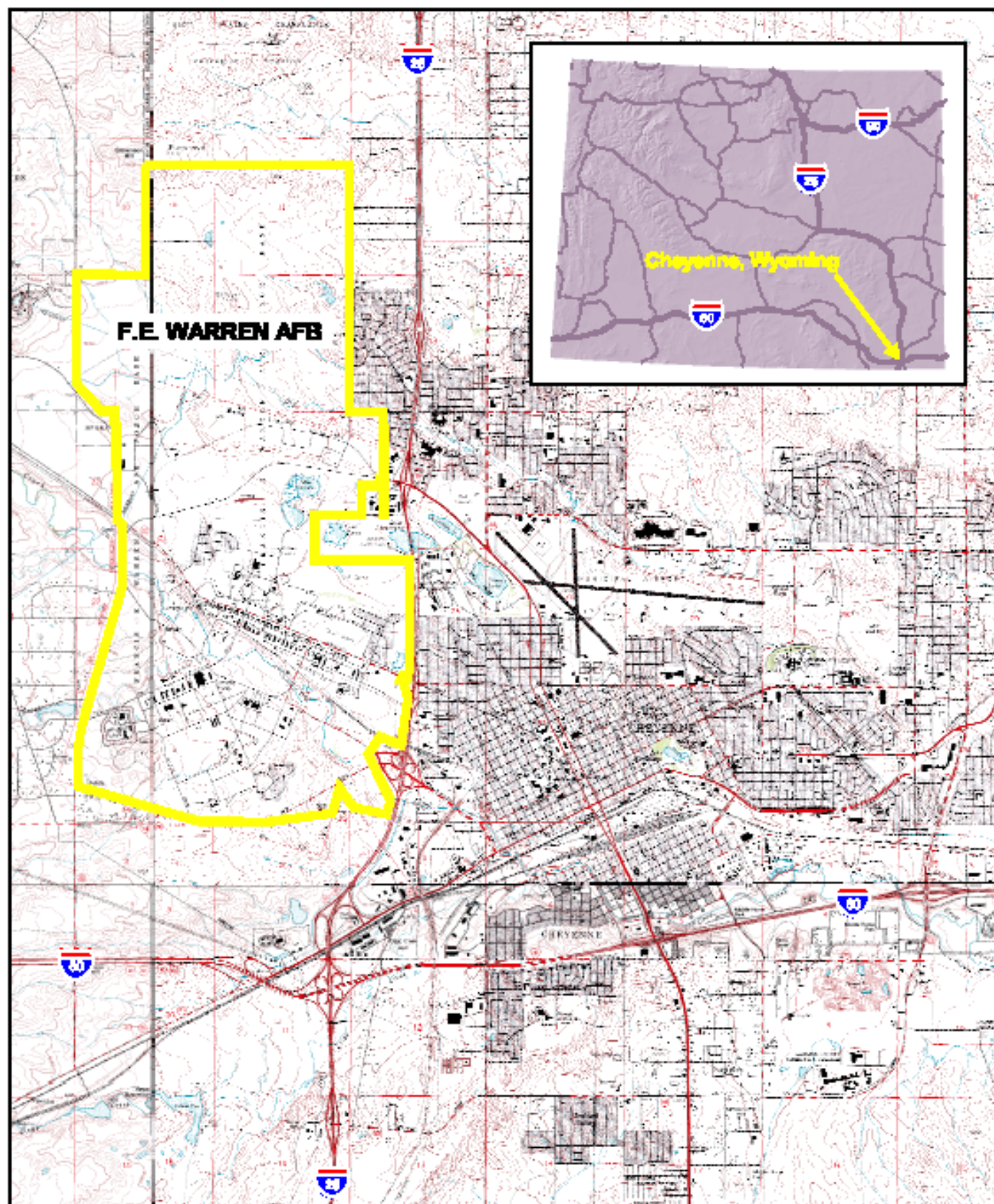
Notes:

● = Acceptable/Best Fit

⊙ = Acceptable/Moderate Fit

○ = Not Acceptable

(1) Alternative does not meet the Threshold Criteria and, therefore, is not an acceptable alternative. Balancing Criteria not evaluated with other alternatives.



0 1 2 Miles

Source: USGS 1:24,000 Digital Topographic Maps

Figure 1-1
Location of F.E. Warren Air Force Base
Cheyenne, Wyoming

F. E. Warren AFB
Landfill 4 Feasibility Study

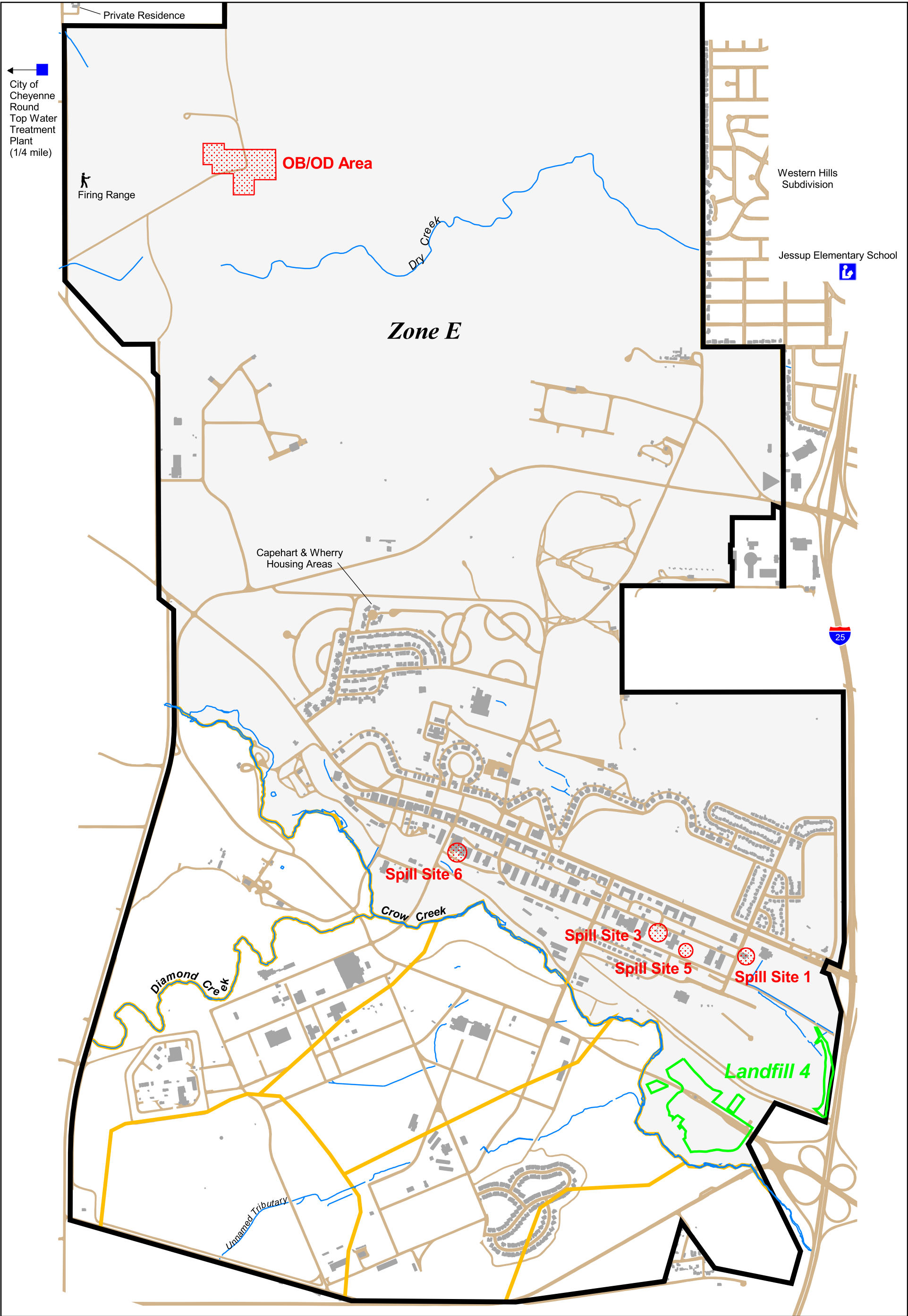


Figure 1-2
Zone E Site Location Map

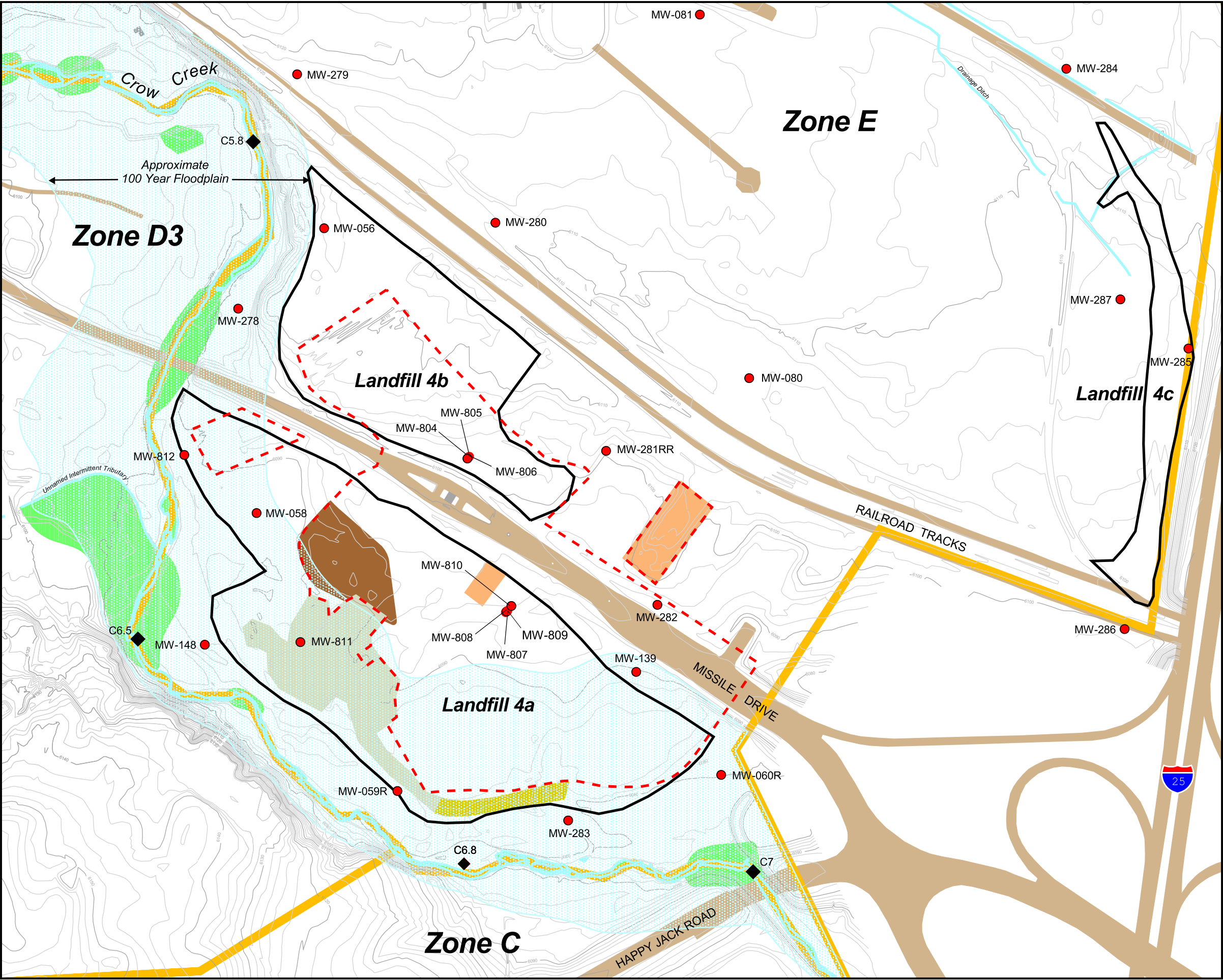
F. E. Warren AFB
Landfill 4 Feasibility Study

Legend	
	Base Boundary
	Zone Boundary
	Waterway
	IRP Site
	Landfill 4
	Zone E

0 1000 2000 Feet

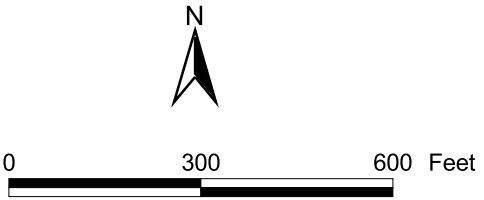


Source: F. E. Warren AFB Environmental Restoration Program



- Legend**
- Existing Monitoring Well
 - Surface Water Sample
 - Approximate Extent of Buried Solid Waste
 - Approximate IRP Landfill Boundary
 - Surface Elevation Contour - 2 ft interval
 - Surface Elevation Contour - 10 ft interval
 - Waterway
 - Approximate 100 Year Floodplain
 - Wetland
 - Unburned Waste Area
 - Suspected Sewage Sludge
 - Exposed Concrete
 - Surficial Debris
 - Building
 - Road
 - Base / Zone Boundary

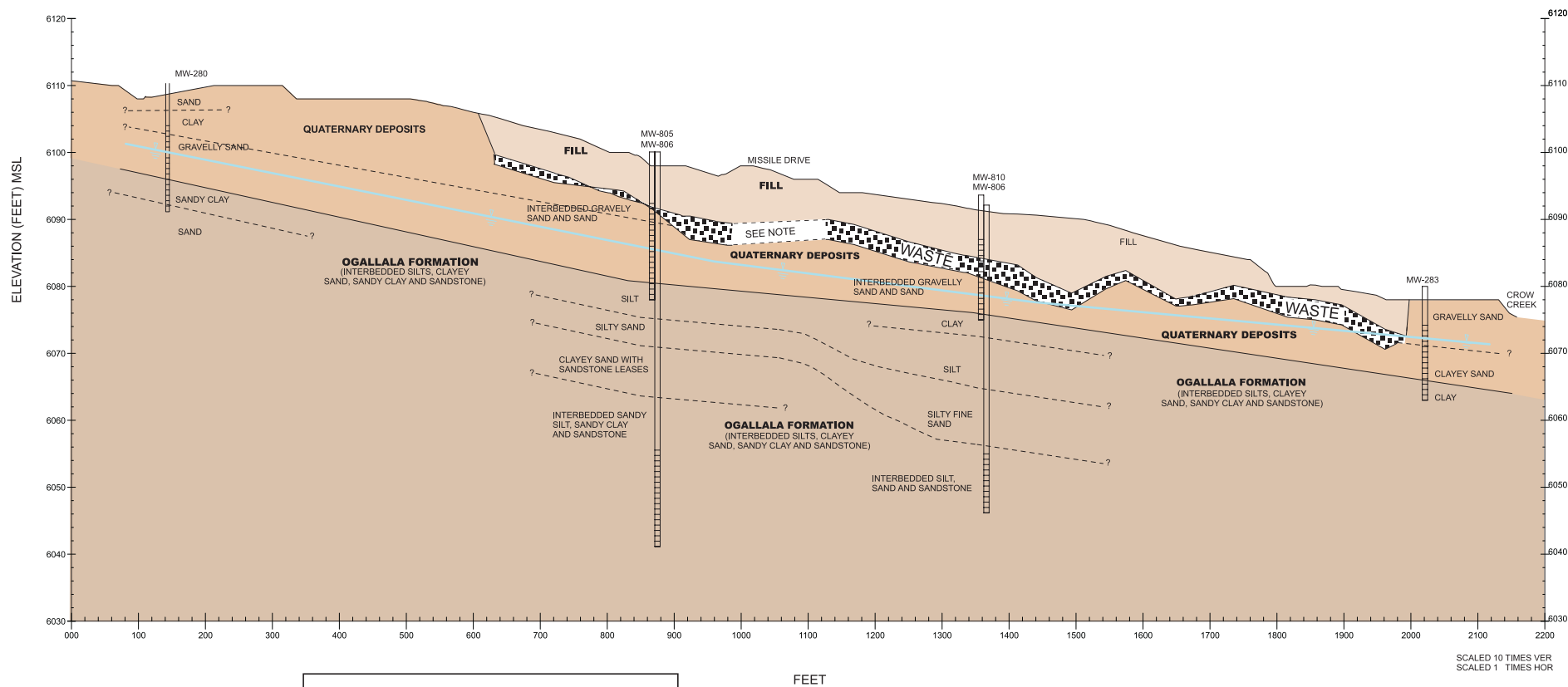
Source
F. E. Warren AFB Environmental Restoration Program
CH2M HILL



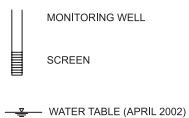
Horizontal Datum: NAD 83
Vertical Datum: NAVD 88

**Figure 1-3
Landfill 4 Site Map**

*F. E. Warren AFB
Landfill 4 Feasibility Study*



LEGEND



HORIZONTAL DATUM: NAD 83
VERTICAL DATUM: NAVD88

NOTE:
WASTE REMOVED FROM BEREATH MISSILE DRIVE.

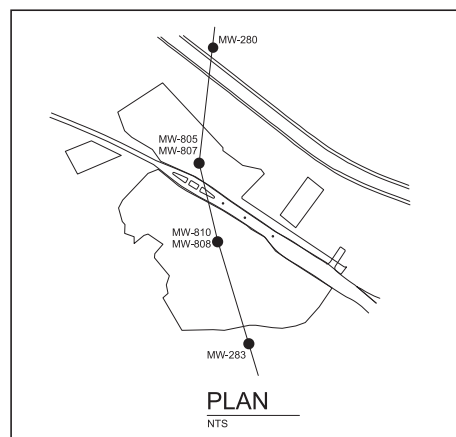


FIGURE 1-4
GENERALIZED GEOLOGIC CROSS SECTION
LANDFILL 4

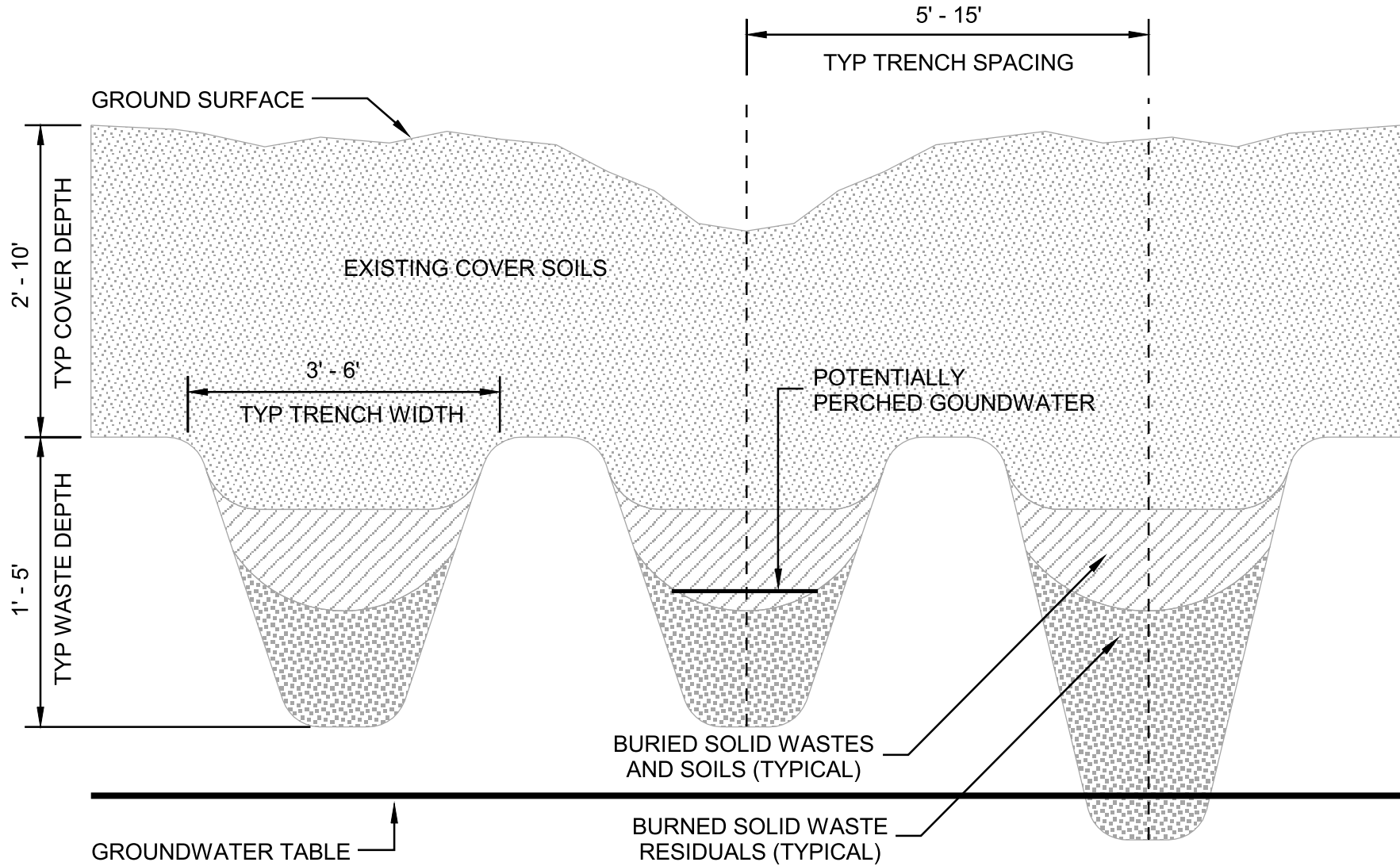
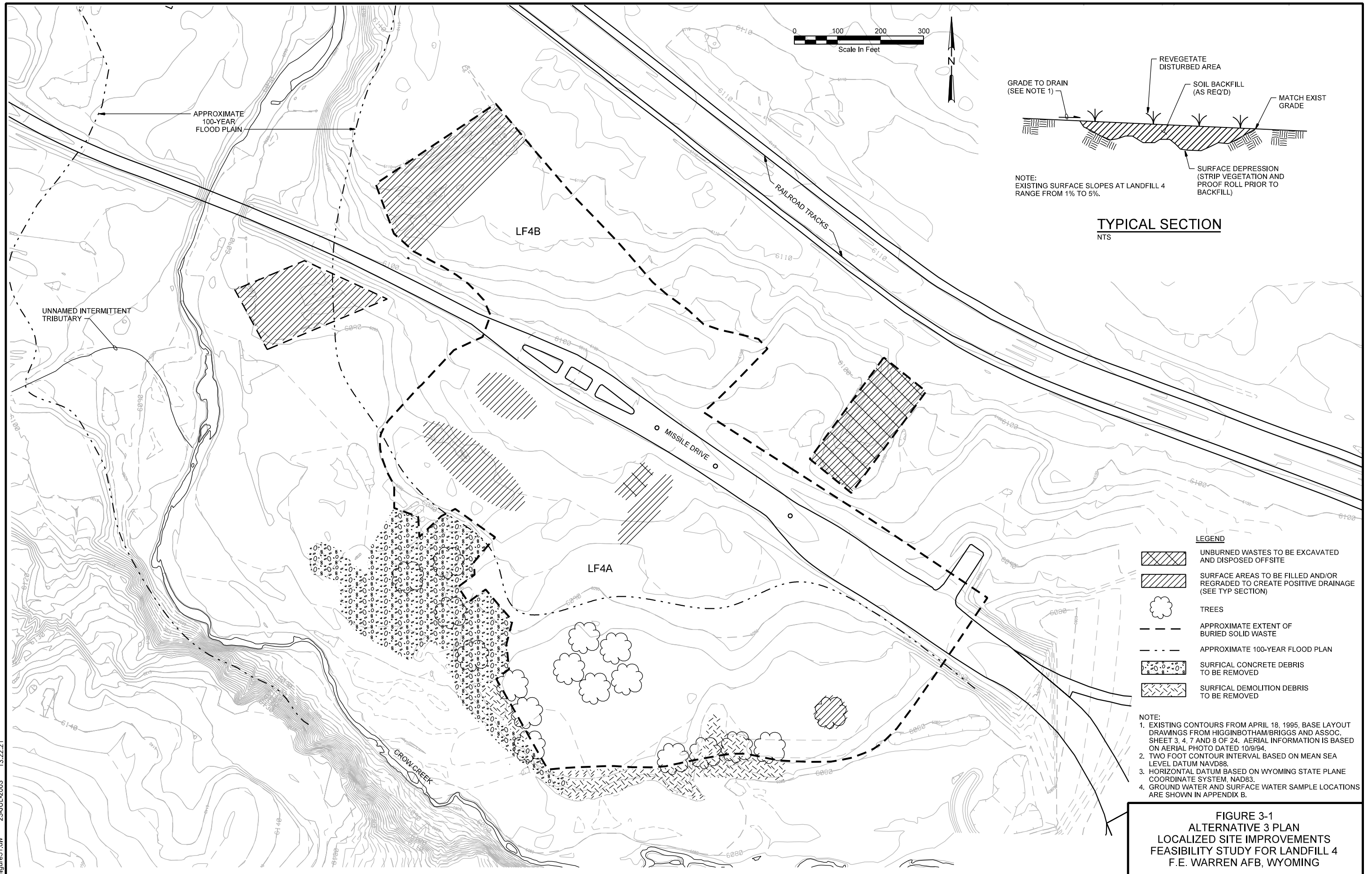
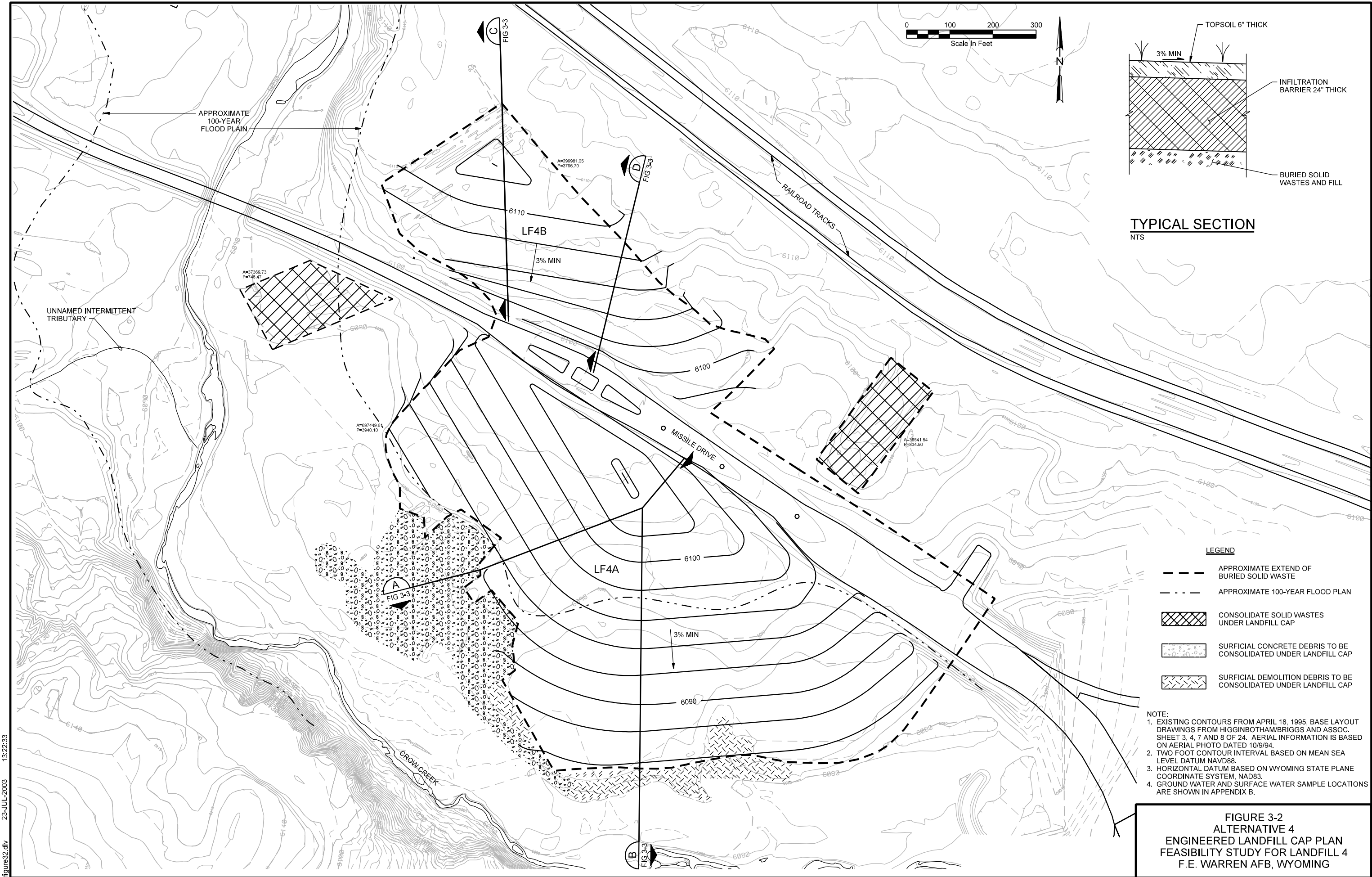
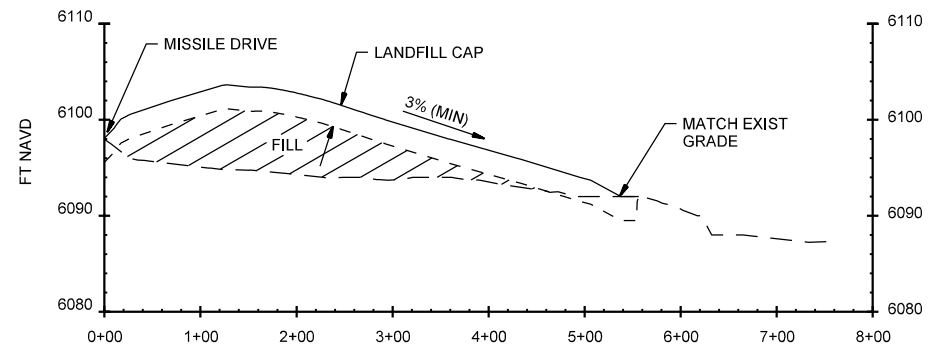


Figure 1-5
Typical Landfill Profile

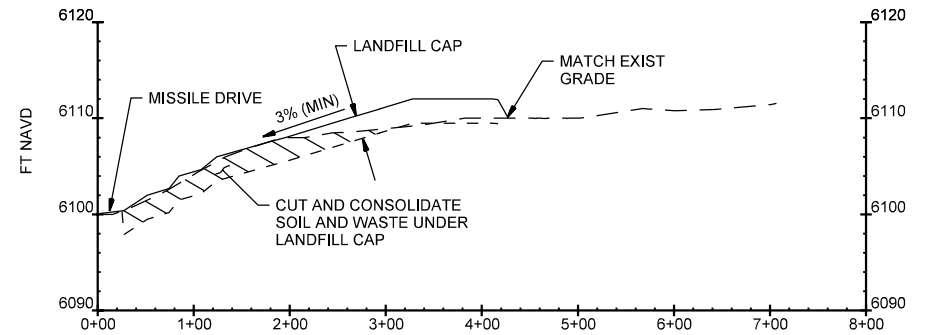
*F. E. Warren AFB
Landfill 4 Feasibility Study*



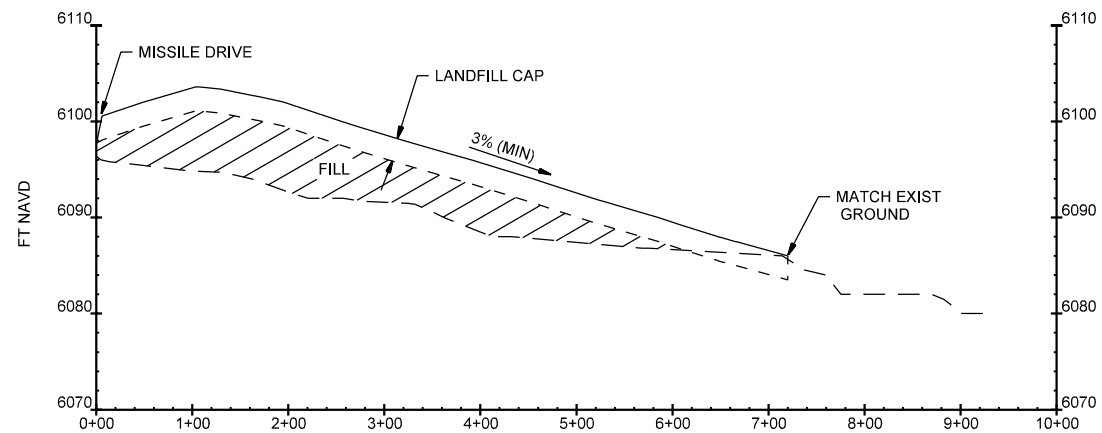




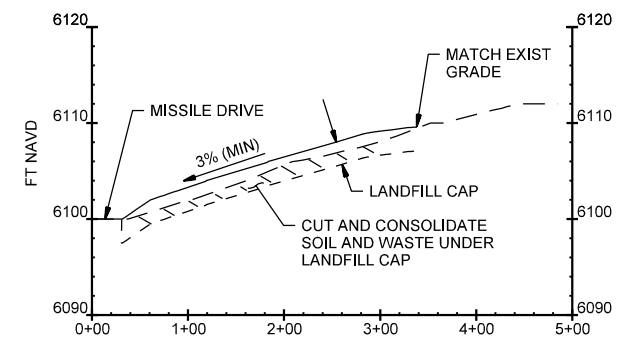
SECTION A
HORIZ: 1"=100'
VERT: 1"=10'
FIG 3-1



SECTION C
HORIZ: 1"=100'
VERT: 1"=10'
FIG 3-1



SECTION B
HORIZ: 1"=100'
VERT: 1"=10'
FIG 3-1



SECTION D
HORIZ: 1"=100'
VERT: 1"=10'
FIG 3-1

LEGEND

- TOP OF LANDFILL CAP
 - - - - BOTTOM OF 30" LANDFILL CAP
 - · - · - TOP OF EXISTING GROUND
- Scaled 10.0000 Times Ver.
Scaled 1.0000 Times Hor.

FT NAVD, FEET NORTH AMERICAN VERTICAL DATUM

**FIGURE 3-3
ALTERNATIVE 4
ENGINEERED LANDFILL CAP SECTIONS
ZONE E RECORD OF DECISION
F.E. WARREN AFB, WYOMING**

Landfill 4 Volume Calculations

This appendix summarizes the basis for estimating the volume of the volume of waste and fill material, cover soil, surficial concrete debris, surficial demolition debris and unburned trash located in Landfill 4 at F.E. Warren Air Force Base, Wyoming.

Cover Soil and Waste Volumes

A test trench/pit investigation was completed at Landfill 4 as part of the Zone E Remedial Investigation (RI) in May and June 2001. The purpose of the test trenches/pits were to estimate the lateral and vertical extent of landfill wastes and to generally characterize the buried solid waste material buried in the landfill. Each test trench/pit was logged, including the observed depth of the cover soils and thickness of waste encountered.

The information from the trench logs was used to create a digital terrain models using InRoads SelectCad Version 8.02. Modeled surfaces included the primary footprint of Landfill 4 and one isolated area of buried waste on the west side of Landfill 4 south of Missile Drive and adjacent to Crow Creek.

- **Ground Surface Terrain Model:** Existing topographic contours generated from 1994 aerial survey data were used to generate a ground surface terrain model (*Map C-1, Base Layout, Base Comprehensive Planning Instruction AFI 32-7062, April 1995*). The horizontal datum was based on the Wyoming State Plane Coordinate System, NAD83. The vertical datum was based on the mean sea level datum, NAVD88. The topographic data was provided in 2-foot contour intervals and the datum. The topographic surface used for the terrain model is shown on **Figure 1**.
- **Top of Waste Terrain Model:** A digital terrain model for the top of the waste was prepared by imposing observed the observed thickness of cover soils from test trench/pit logs onto a 100 foot by 100 foot grid system.
- **Bottom of Waste Terrain Model:** A digital terrain model for the bottom of the waste was prepared by imposing observed the observed thickness of west from test trench/pit logs onto the same 100 foot by 100 foot grid system as for the top of waste terrain model.

Using the terrain model described above, computer-generated volume calculations were completed for the primary footprint of Landfill 4 and one isolated area of buried waste on the west side of Landfill 4 south of Missile Drive and adjacent to Crow Creek.

- **Figure 2** documents the observed thickness and estimated total volume of cover soil, buried solid waste and fill material for each area.
- **Figure 3** documents the observed thickness and estimated volume of cover soil for each area.

- **Figure 4** documents the observed thickness and estimated volume of buried solid waste. Note that the volume of buried solid waste shown in Figure 4 is the total volume of waste in the individual trenches and the “intermixed” soil between the waste trenches.

General Volume Calculations

In addition to the computer-generated volume calculations, general volumes were also generated for smaller areas of the Landfill as follows:

- Approximately 18,000 cubic yards of cover soil and unburned trash was observed east of Landfill 4b based on a footprint of approximately 1.0 acres and a typical thickness of 13 feet. The thickness of the cover soils was assumed to be approximately 4 feet, corresponding to approximately 6,000 cubic yards of cover soils. The thickness of the waste and fill material underlying the cover soils was approximately 9 feet, corresponding to approximately 13,000 cubic yards of buried solid waste and fill material.
- Approximately 1,000 cubic yards of unburned trash and 2,000 cubic yards of cover soil was estimated for a small area (<1/4 acre) identified in Landfill 4a. The amount of unburned trash is based on an average waste thickness of 3 feet. The amount of cover soil is based on an average cover soil thickness of 5 feet.
- Approximately 10,000 cubic yards of exposed concrete demolition debris has been “stockpiled” along the southern boundary of Landfill 4a. This estimate assumes the concrete encompasses approximately 3 acres and is typically 3 feet thick. A factor of 0.75 was applied to account for the void space within the concrete piles. A small volume of exposed concrete (<1,000 cubic yards) is also present in the Landfill 4b area along the Crow Creek embankment.
- Approximately 1,000 cubic yards (based on field observations) of exposed demolition debris (primarily singles, siding, etc.) was observed along the southern boundary of Landfill 4a. Although not quantified, some of the material may be asbestos-containing materials. Further inspection and sampling by a qualified industrial hygienist is needed to determine the type of material present and proper handling and disposal requirements.
- Approximately 10,000 of suspected sewage sludge or similar material was identified buried in the Landfill 4a area. No records were located to indicate that this type of waste was disposed in Landfill 4, but it is known that the base wastewater treatment plant was in operation while Landfill 4 was being used.

Summary of Calculations

A summary of the volume of cover soil, buried solid waste and fill material, and related waste streams is presented in **Table 1**. The estimated volume of cover soil, buried solid waste and fill, and suspected sewage sludge is approximately 290,000 cubic yards. Approximately 10,000 cubic yards of exposed concrete and demolition debris is present on the surface of Landfill 4, primarily along the southern edge of the Landfill 4a area.

Based on the estimated volumes, the following conclusions can be made about Landfill 4:

- Approximately 290,000 cubic yards of cover soil, buried solid waste and intermixed soils, and suspected sewage sludge are present in Landfill 4.
- Approximately 190,000 cubic yards of cover soil is present in Landfill 4. The cover thickness ranged from 2 feet to 10 feet. The calculated average depth of the cover soil is approximately 4.2 feet, which is consistent with the observed thickness during the trenching investigation.
- Approximately 100,000 to 110,000 cubic yards of buried solid waste and intermixed soils, and suspected sewage sludge is present in Landfill 4. The buried solid waste thickness generally ranged from 1 foot to 5 feet. The calculated average depth of the buried solid waste is approximately 2.5 feet, which is consistent with the observed thickness during the trenching investigation.
- Approximately 10,000 cubic yards of exposed concrete demolition debris has been “stockpiled” along the southern boundary of Landfill 4a. This estimate assumes the concrete encompasses approximately 3 acres and is typically 3 feet thick. A factor of 0.75 was applied to account for the void space within the concrete piles. A small volume of exposed concrete (<1,000 cubic yards) is also present in the Landfill 4b area along the Crow Creek embankment.

Uncertainty Analysis

The volume calculations presented above should be considered a reasonable order of magnitude estimate using available information to date. Because the topographic survey data used was accurate to 2-foot contours, many of the surface features are likely not accurately presented. Such uncertainties may result in significant differences in the estimated volumes presented above. Assuming a landfill footprint of 25 acres for wastes that are buried (i.e. 3 acres for surficial wastes), deviations of ± 1 foot would result in a volume difference of approximately 40,000 cubic yards.

TABLE 1

Estimated Volume of Cover, Solid Waste and Construction/Demolition Debris in Landfill 4
Feasibility Study for Landfill 4

Location	Area ^a (acres)	Volume of Cover Soil and Buried Solid Waste/Fill (CY)	Cover Soils ^b (CY)	Buried Solid Waste/Fill ^c (CY)	Other Buried Solid Waste Identified in Landfill (CY)	Surficial Concrete and Demolition Debris (CY)
Landfill 4a (South of Missile Drive	1.0 acres (west area) 19.0 acres (east side)	3,698 (west area) 197,706 (east area)	2,918 (west area) 128,781 (east area)	1,050 (west area) 68,925 (east area)	10,000 (suspected sewage sludge, buried)	10,000 (concrete debris) 1,000 (demo debris)
Landfill 4b	7.0 acres	62,739	51,117	11,622	---	1,000 (concrete debris)
Area East of Landfill 4b	1.0 acres	18,000	6,000	13,000	---	---
Landfill 4c	(see note d)	(see note d)	(see note d)	(see note d)	(see note d)	(see note d)
Subtotal:	28 acres	282,143	188,816	94,957	12,000	12,000
Round To:	28 acres	290,000 ^e	190,000 ^e	100,000 ^e	10,000	10,000

NOTES:

CY = Cubic yards

LF4a = Landfill 4a

LF4b = Landfill 4b

LF4c = Landfill 4c

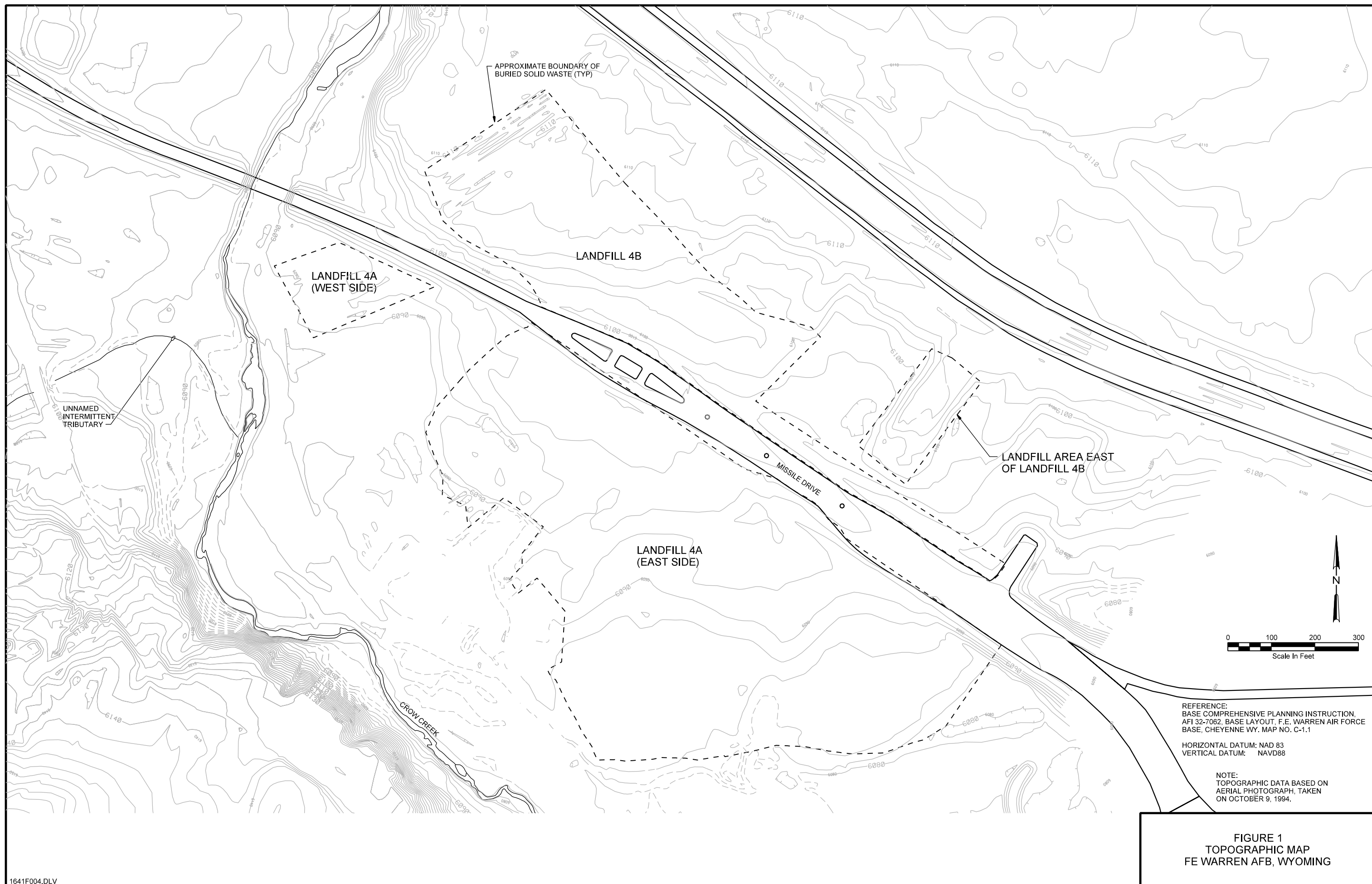
^a The waste area was determined by the trenching investigation and correlation with aerial photography.

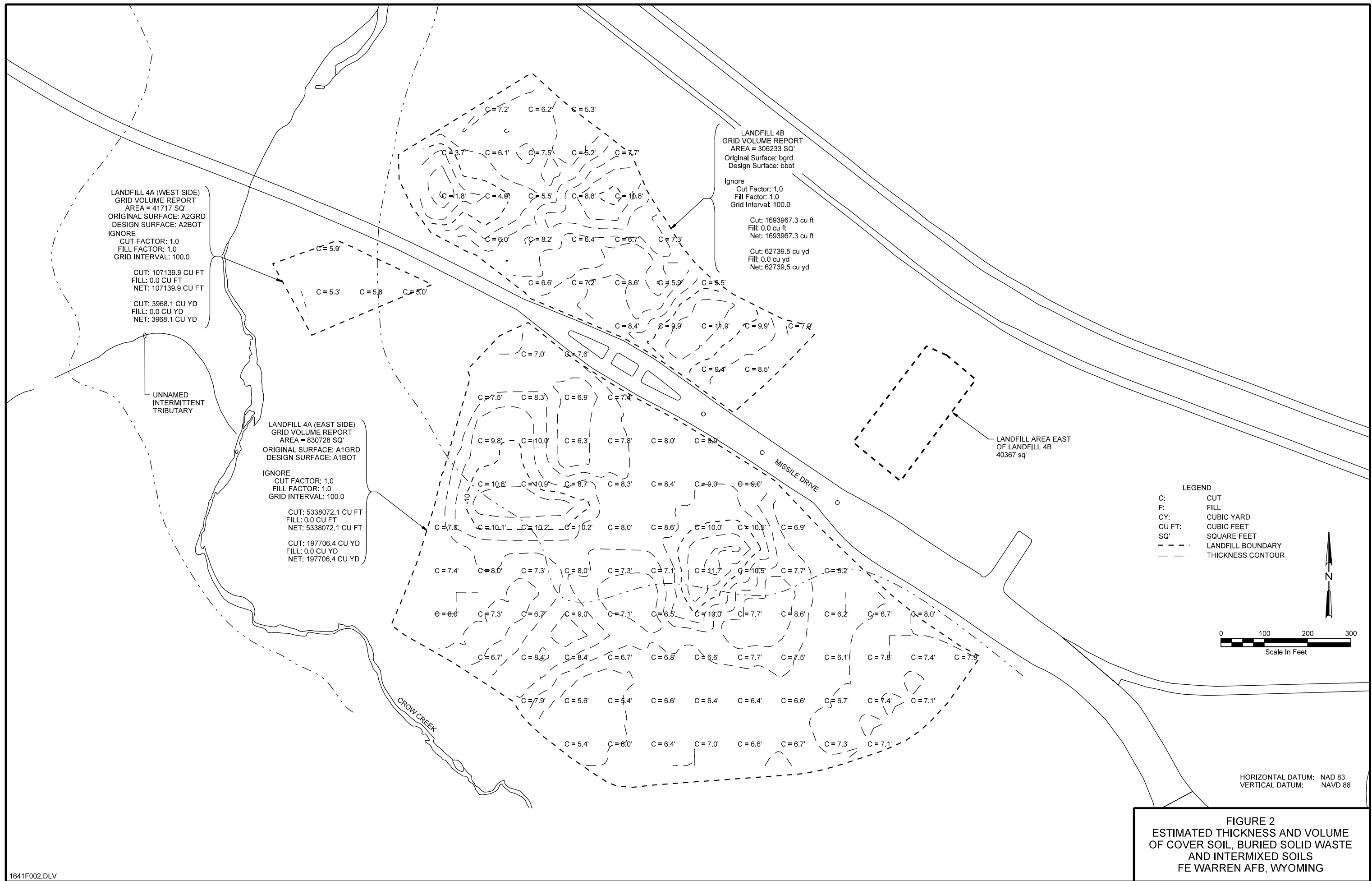
^b The existing cover is comprised of soil fill with concrete and demolition debris intermixed in some areas.

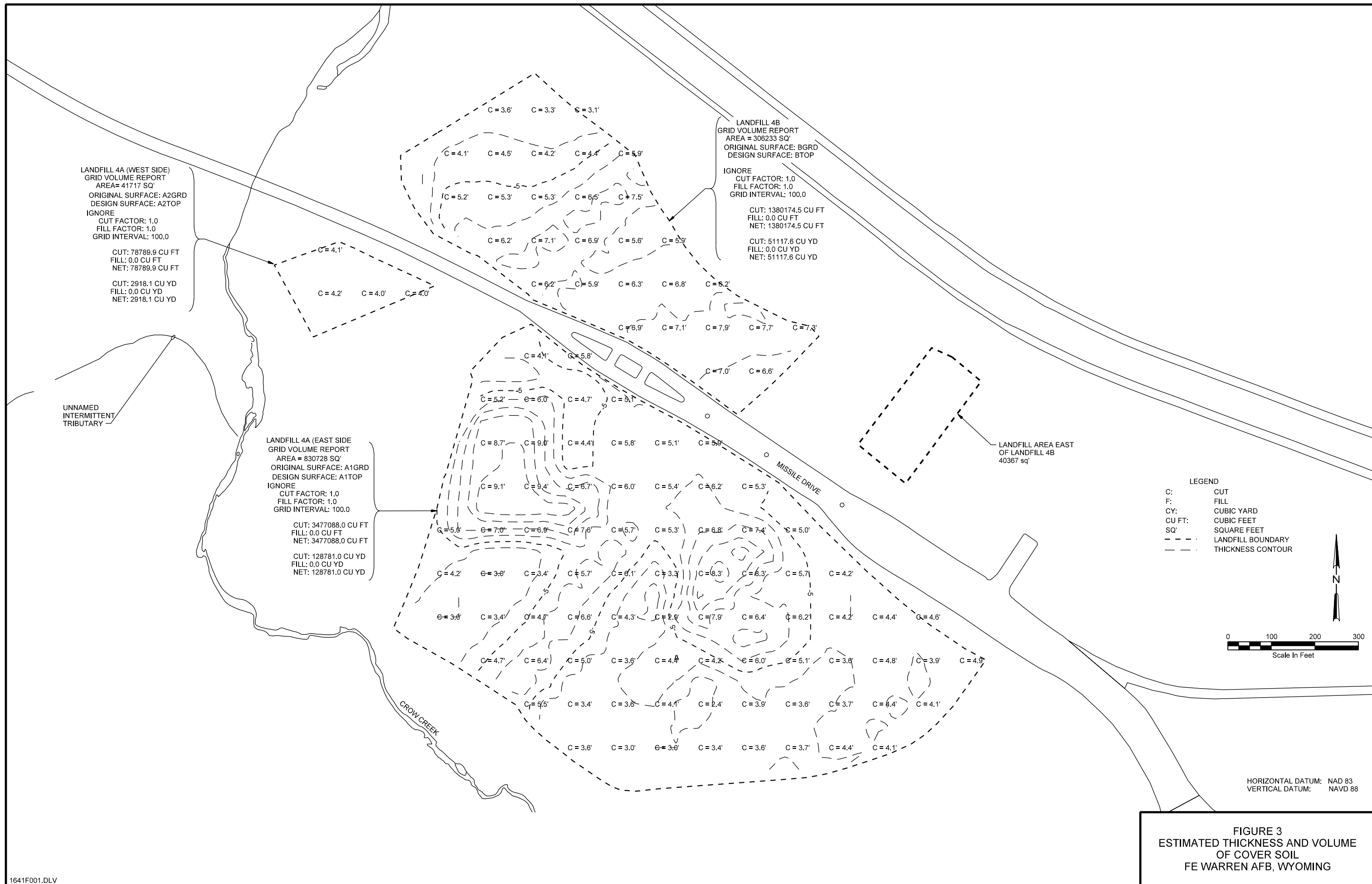
^c Buried solid waste includes residuals from burning, unburned waste, and inert materials such as paper, glass and metals. The soils that are intermixed with the solid waste as well as the native soils between waste trenches are included in the estimate above.

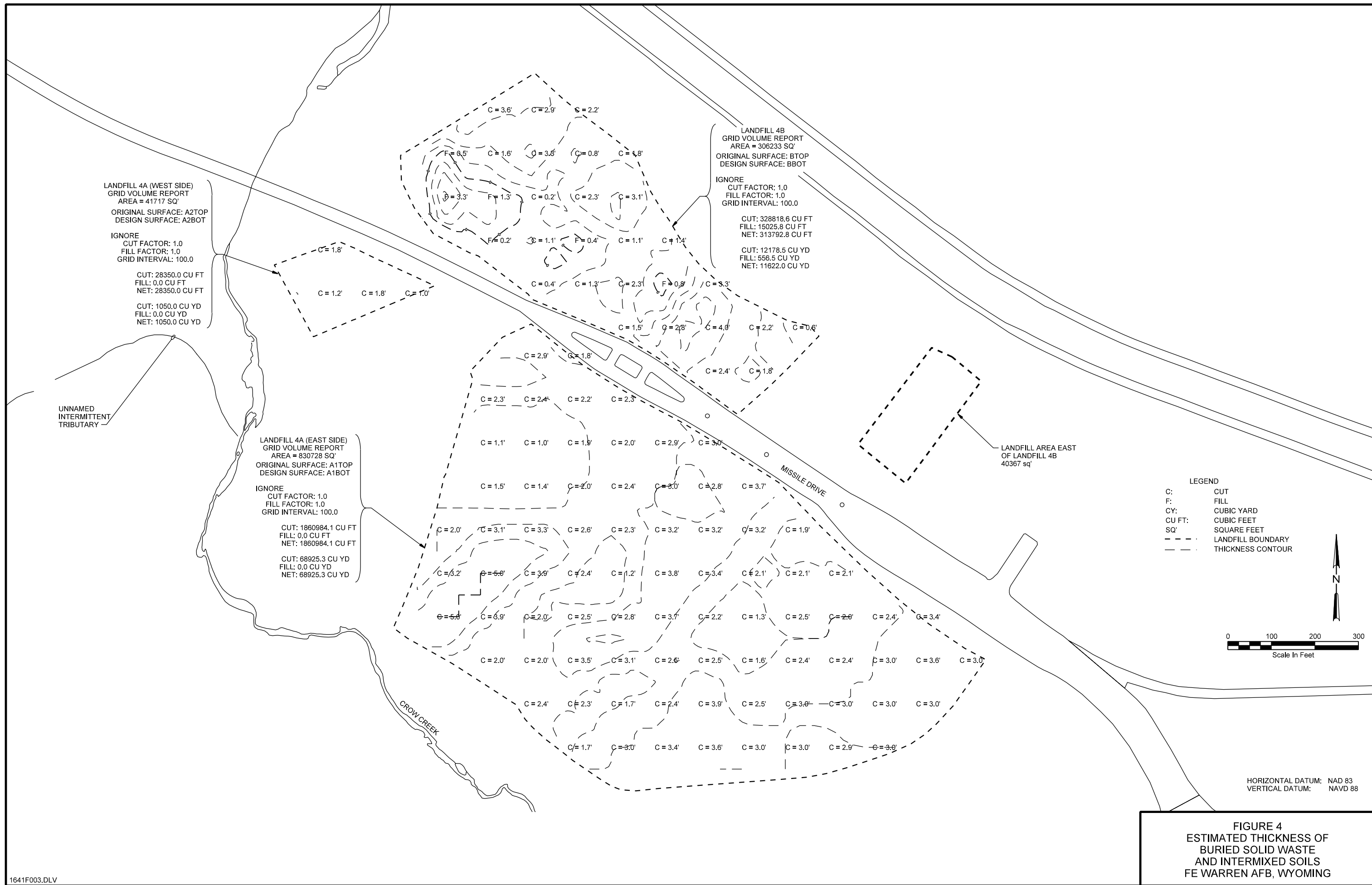
^d No solid waste was encountered in LF4c.

^e Variations of ± 1 foot may result in volume differences of 40,000 cubic yards.









APPENDIX B

Groundwater and Surface Water Monitoring Plan for Landfill 4, F.E. Warren AFB, Wyoming

1.0 Introduction

The USAF recognizes that additional data needs to be collected to reduce the uncertainty associated with the concentrations of iron and manganese in groundwater, therefore the monitoring plan will be fully developed during the design phase. The refined and fully developed monitoring plan will outline the additional data to be collected and the methods to be used to assess whether iron and manganese concentrations are background concentrations or not.

This groundwater and surface water monitoring plan (monitoring plan) is for Alternatives 3 and 4 presented in the Feasibility Study (FS) for Landfill 4. The key objectives of the monitoring plan are to: (1) outline how groundwater and surface water monitoring will be used to satisfy the requirements of Remedial Action Objective (RAO) Number 4 (RAO 4), which addresses the uncertainties associated with groundwater at Landfill 4 identified in the Remedial Investigation (RI) Report; and (2) outline how the long-term effectiveness of Alternatives 3 and 4 will be monitored.

2.0 Background

The Landfill 4 RI concluded that:

"Iron and manganese are elevated above SMCLs and WDEQ groundwater standards in groundwater beneath and downgradient of Landfill 4. However, evaluation of geochemistry and iron and manganese concentrations using cumulative probability plots indicates that iron and manganese in groundwater are naturally occurring background concentrations. Therefore, iron and manganese are not identified as COPCs in the HHRA. Low oxidizing groundwater conditions which occur in some areas beneath Landfill 4 (MW-804, MW-807 and MW-810) and downgradient of Landfill 4 (MW-59) cause iron and manganese to be released from the aquifer and become dissolved in shallow groundwater. The areas of lower oxidizing condition could represent groundwater impacted from the landfill or a natural decrease in Oxidation-Reduction Potential (Eh) along the groundwater flowpath. It is considered most likely that the lower oxidizing condition is associated with a natural decrease in Eh, rather than landfill impact on the Eh. The reason for this interpretation is because of the high naturally occurring TOC concentrations, which control Eh, and because there is no continuity between the two sampling rounds for these four well locations. In some areas beneath and downgradient of Landfill 4 the groundwater system is more oxidizing, resulting in iron and manganese being precipitated out of the groundwater before the groundwater discharges to Crow Creek. The localized areas and rate at which iron and manganese attenuate beneath and downgradient of Landfill 4 is dependent on the Eh and pH conditions."

The following uncertainties were identified in the RI Report:

"The concentrations of iron and manganese in groundwater beneath and downgradient of Landfill 4 were assessed to be background concentrations. The low oxidizing groundwater conditions which

occur in some areas beneath Landfill 4 and downgradient of Landfill 4 cause iron and manganese to be released from the natural aquifer materials and become dissolved in shallow groundwater. It is considered most likely that the lower oxidizing condition is associated with a natural decrease in oxidation-reduction potential along the groundwater flowpath (due to the naturally high total organic carbon concentrations), rather than a landfill impact on the oxidation-reduction potential, however this is uncertain.

Additional data collection in the form of surface water flow and quality monitoring, and monitoring of groundwater elevations and concentrations of contaminants is recommended to verify the conclusions of this RI. Additional wells may be needed during the monitoring to enable sufficient data to be collected to address these uncertainties."

Although the RI report concluded that the concentrations of iron and manganese in groundwater are likely naturally occurring background concentrations, this is uncertain because the high total organic carbon concentrations in groundwater may either be naturally occurring or a result of the landfill waste. In addition, the shallow groundwater beneath and downgradient of Landfill 4 may be a mix of groundwater from three different flow paths: (1) lateral groundwater flow from upgradient of the landfill; (2) upward groundwater flow from deeper water bearing units beneath the landfill; and (3) lateral groundwater flow in the floodplain adjacent to and parallel to Crow Creek, and flowing from upstream. Initial investigation (in the RI) of the geochemistry of these three different sources of groundwater indicate that they have similar geochemical characteristics and therefore have similar naturally occurring background concentrations. However, additional data is required to confirm this initial investigation.

The following RAO (RAO 4) was identified to address the uncertainty associated with iron and manganese concentrations and geochemical influences on the iron and manganese concentrations in groundwater beneath and downgradient of Landfill 4.

"Restore ground water to beneficial use, which in this case is restoration of iron and manganese to background conditions. Background conditions are best evaluated through future monitoring to address temporal and spatial variations. If iron and manganese concentrations in ground water at Landfill 4 are confirmed to be background through future monitoring, there will be no further requirement for restoration."

This monitoring plan outlines the methodology that will be used to address RAO 4. The data collected will be used to verify the RI finding that the concentrations of iron and manganese exceeding groundwater standards are within the range of naturally occurring background levels and are not adversely influenced by Landfill 4. The data collected will also be used to verify that the low oxidizing geochemical condition occurring in some parts of the shallow groundwater beneath Landfill 4 is naturally occurring and is not caused by Landfill 4 waste. If it is determined that Landfill 4 is contributing to groundwater contamination, or causing an unfavorable change in groundwater geochemistry, the potential need for remedial actions to restore groundwater to background concentrations would be assessed.

Although the concentrations of some compounds (e.g. manganese) in Crow Creek surface water exceeded the surface water standards both upstream and downstream of Landfill 4, the RI Report concluded that Landfill 4 does not impact Crow Creek. Therefore, an RAO to address surface water along Crow Creek was not required. However, future monitoring of

surface water in Crow Creek in conjunction with the groundwater monitoring will be used to check if future exceedances, if any, are related to Landfill 4.

3.0 Monitoring Objectives

The objectives of the monitoring plan are to:

- Satisfy RAO 4 by monitoring the concentrations of iron and manganese detected in groundwater beneath and downgradient of Landfill 4 to confirm whether or not they are background concentrations and resolving the uncertainty of whether or not the low oxidizing Eh values beneath Landfill 4 are naturally occurring.
- Monitor the long-term performance of the selected remedy to confirm that the landfill does not contribute iron and manganese (or other parameters) to groundwater or surface water in the future.

4.0 Monitoring Approach

A “decision tree approach” will be used to guide the data collection and interpretation of the results. Figure 1 outlines the decision tree approach. An overview of the steps outlined in the decision tree is provided below. Detailed information for each step is provided in Sections 5.0 through 9.0.

In Step 1, additional deep and intermediate depth monitoring wells will be installed upgradient and downgradient of Landfill 4. Data from these wells will be used to resolve uncertainties associated with the groundwater system at Landfill 4. Step 2 of the monitoring plan is the collection of groundwater and surface water samples on a quarterly basis for three years. The quarterly samples will provide data during seasonal fluctuations in the groundwater and surface water system.

The quarterly samples collected over three years will be used to evaluate the following:

- (a) Are the range of background concentrations of iron and manganese in groundwater consistent with the findings of the RI Report that iron and manganese are present in groundwater at naturally occurring background concentrations?
- (b) Does the landfill adversely impact the geochemistry of the groundwater system beneath or downgradient of the landfill?

Depending on the answers to questions (a) and (b), there may be two possible scenarios for Step 3 of the monitoring plan:

1. Begin long-term monitoring to confirm that the landfill does not contribute iron and manganese (or other parameters) to groundwater or surface water in the future. This action would be taken if the background concentrations of iron and manganese determined in the RI are confirmed and that the uncertainty associated with the geochemistry is sufficiently resolved to indicate that the landfill is not affecting the geochemistry of the groundwater system.
2. Undertake further investigation and/or assess whether a remedial action is required to satisfy RAO 4 and restore groundwater to beneficial use. If a remedial action is instigated, long-term monitoring would still be undertaken to assess the effectiveness of

the remedy and/or assess whether the concentrations are being geochemically attenuated.

Each of the three monitoring steps and two decision steps of the groundwater monitoring plan are discussed in further detail in the following sections.

5.0 Step 1: Installation of Additional Monitoring Wells

The first step of the groundwater and surface water monitoring plan is to install two clusters of intermediate and deep wells upgradient and three clusters downgradient of Landfill 4 (ten additional wells in total). It is proposed that the well clusters would be installed adjacent to the following existing shallow wells: MW-280, MW-281RR, MW-148, MW-283 and MW-060R. The location of the proposed new wells and groundwater flow paths are shown on Figure 2. The target depths and rationale for each well is provided in Table 1.

The additional intermediate and deep wells will provide data to better understand groundwater flow paths at Landfill 4 and vertical groundwater gradients. Groundwater samples from these additional wells in conjunction with existing wells will provide additional data to assess the uncertainties associated with the geochemistry of the groundwater system at Landfill 4.

6.0 Step 2: Monitoring to Confirm Background and Address Uncertainties

Step 2 of the monitoring plan is the collection of groundwater and surface water samples on a quarterly basis for three years. The additional data and the data collected during the RI will be used to make the decisions outlined in Figure 1 and Section 4.0 of this monitoring plan. The data will also be used to indicate seasonal influences on groundwater flowpaths and chemistry.

The first year of quarterly groundwater and surface water sampling will involve the collection of groundwater samples from 21 existing monitoring wells, the 10 new monitoring wells and four surface water sampling locations. The locations of the groundwater and surface water sampling locations are shown on Figure 2.

The groundwater and surface water samples would be analyzed for total and dissolved metals, major cations and anions, total dissolved solids (TDS), total suspended solids (TSS), total organic carbon (TOC), ammonia, nitrate, nitrite and total Kjeldahl nitrogen, volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). The total and dissolved metals data will be used to assess the concentrations of iron, manganese and other metals in groundwater. VOC and SVOC data will be used to confirm the results of the RI that the concentrations of organics in groundwater were low and infrequently detected. Major cations and anions, TDS, TSS, TOC, ammonia, nitrate, nitrite and total Kjeldahl nitrogen data will be used to assess the geochemistry of the groundwater system. In addition, pH, temperature, oxidation-reduction potential, dissolved oxygen (DO) and specific conductance will be measured during the sample collection to also assess the geochemistry of the groundwater system. Table 2 outlines the proposed parameters to be analyzed in the groundwater and surface water samples:

Table 1 Proposed Monitoring Well Details

Proposed Well Number	Target Well Depth	Rationale for Well Location
PMW-1	Intermediate	Provide a cluster of wells upgradient of Landfill 4 adjacent to existing well MW-280 to assess the vertical groundwater gradient and chemistry of intermediate and deeper groundwater. This data will be used to assess the influence of upgradient shallow, intermediate and deeper groundwater on the geochemistry and concentrations of iron and manganese.
PMW-2	Deep	
PMW-3	Intermediate	Provide a cluster of wells upgradient of Landfill 4 adjacent to existing well MW-281RR to assess the vertical groundwater gradient and chemistry of intermediate and deeper groundwater. This data will be used to assess the influence of upgradient shallow, intermediate and deeper groundwater on the geochemistry and concentrations of iron and manganese. Two upgradient clusters were chosen to allow evaluation along two different groundwater flow paths.
PMW-4	Deep	
PMW-5	Intermediate	Provide a cluster of wells downgradient of Landfill 4 adjacent to existing well MW-148 to assess the vertical groundwater gradient and chemistry of intermediate and deeper groundwater and the influence of shallow groundwater flowing adjacent to Crow Creek. This data will be used to assess the influence of shallow, intermediate and deeper groundwater on the geochemistry and concentrations of iron and manganese downgradient of Landfill 4. This cluster of wells is located to be on the approximate same flow path as the cluster of wells PMW-1 and PMW-2.
PMW-6	Deep	
PMW-7	Intermediate	Provide a cluster of wells downgradient of Landfill 4 adjacent to existing well MW-283 to assess the vertical groundwater gradient and chemistry of intermediate and deeper groundwater and the influence of shallow groundwater flowing adjacent to Crow Creek. This data will be used to assess the influence of shallow, intermediate and deeper groundwater on the geochemistry and concentrations of iron and manganese downgradient of Landfill 4. This cluster of wells is located to be on the approximate same flow path as the cluster of wells PMW-3/PMW-4 and MW-807/MW-808/MW-810.
PMW-8	Deep	
PMW-9	Intermediate	Provide a cluster of wells downgradient of Landfill 4 adjacent to existing well MW-60R to assess the vertical groundwater gradient and chemistry of intermediate and deeper groundwater and to investigate whether the higher iron and manganese concentrations at this location are related to intermediate or deeper groundwater. This data will be used to assess the influence of shallow, intermediate and deeper groundwater on the geochemistry and concentrations of iron and manganese downgradient of Landfill 4.
PMW-10	Deep	

Table 2 Proposed List of Parameters to be Analyzed for Surface Water and Groundwater

Field Parameters (pH, specific conductance, dissolved oxygen, oxidation-reduction potential, temperature)	Major Anions (bicarbonate, chloride,)
Total and Dissolved Metals (aluminum, antimony, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, zinc)	Total Dissolved Solids
Major Cations (calcium, magnesium, potassium)	Total Suspended Solids
Nitrate, Nitrite and Total Kjeldahl nitrogen	Total Organic Carbon
Volatile Organic Compounds	Ammonia
Semi-volatile Organic Compounds	

7.0 Decision 1: Are Iron and Manganese Concentrations Confirmed as Background?

The iron and manganese concentrations measured during the RI were determined to be naturally occurring background concentrations based on the supplemental background evaluation completed in the RI. The supplemental background evaluation used cumulative probability plots and geochemistry to assess whether the concentrations of iron and manganese in groundwater were background. The concentrations of total and dissolved iron and manganese in groundwater upgradient, within and downgradient of Landfill 4 all plotted on a single straight line on the cumulative probability plots (Figures 3 to 6), thus indicating that iron and manganese were from a single background population. Iron and manganese concentrations in groundwater from the F.E. Warren Basewide Background dataset also plotted on the same straight line, indicating that there is no significant difference between the Landfill 4 and background groundwater.

The maximum background concentrations of dissolved iron and total and dissolved manganese in groundwater at Landfill 4 were estimated from the upper asymptote boundaries on the cumulative probability plots. The upper asymptotic boundary of dissolved iron (see Figure 4) represents a solubility boundary in the groundwater probably constrained by the oxidizing conditions present in the groundwater. This represents the upper background concentration of the dissolved iron which was estimated to be approximately 10,000 µg/L ($\ln(10,000 \text{ µg/L}) = 9.21 \text{ µg/L}$) using data collected during the RI Report. The upper background concentration for total iron (see Figure 5) could not be determined from the cumulative probability plots due to the large influence of iron precipitates and colloids associated with sample turbidity. The upper asymptotic boundaries of the total and dissolved manganese (see Figures 5 and 6) are consistent and indicate an upper background concentration which was estimated to be approximately 4,000 µg/L ($\ln(4,000 \text{ µg/L}) = 8.29 \text{ µg/L}$) using data collected during the RI.

Although the upper range of the iron and manganese background concentrations is greater than the basewide background or upgradient concentrations, these higher concentrations occur as iron and manganese are naturally released from the aquifer materials. Iron and manganese are believed to be naturally released from aquifer materials as a result of natural changes in Eh driven by high naturally occurring TOC in the groundwater at Landfill 4. However, the areas of lower oxidizing conditions could also represent groundwater impacted from the landfill or a natural decrease in Eh along the groundwater flow path. This will be further evaluated in Section 8.0.

The data collected during the first three years of monitoring will be added to the RI data and evaluated to assess whether the concentrations of iron and manganese are naturally occurring background concentrations or not. One of the techniques that will be used to make this assessment will be plotting the data on the cumulative probability plots shown on Figures 3 through 6. In conjunction with the results of other evaluation techniques, the concentrations of iron and manganese in groundwater may be considered background if:

1. The iron and manganese concentration data and the RI concentration data plots on the same line and forms a single population on the cumulative probability plots.
2. The concentration of dissolved iron does not exceed the upper asymptotic boundary of the naturally occurring background concentrations.
3. The concentration of total and dissolved manganese does not exceed the upper asymptotic boundary of the naturally occurring background concentrations.

If these three criteria are satisfied, then the potential impact of Landfill 4 on the Eh of the groundwater will be considered before iron and manganese can be confirmed to be background. The method for evaluating this is discussed in Section 8.0.

8.0 Decision 2: Is the Geochemistry Uncertainty Sufficiently Resolved?

As discussed in Section 7.0, the higher concentrations of iron and manganese in groundwater (compared to upgradient wells and the basewide background) are believed to occur because iron and manganese are naturally released from the aquifer materials. However, the data from some wells within and downgradient of Landfill 4 are part of a second lower oxidizing Eh population on the Eh cumulative probability plot (see Figure 7). This lower oxidizing population imparts some uncertainty on whether the concentrations of iron and manganese in groundwater are due to groundwater impacted from the landfill or a natural decrease in Eh along the groundwater flowpath. Based on the temporal inconsistency of the Eh measurements for each well for different sampling events (i.e. Eh data from the same wells collected during separate sampling events fall on both the upper and lower line of the cumulative probability plot), it is thought that the lower oxidizing condition is most likely caused by a natural decrease in Eh due to the high naturally occurring total organic carbon (TOC) in the aquifer, rather than a landfill impact on the Eh. Microbial activity, which can be represented by TOC, essentially controls the Eh of groundwater systems. The high TOC concentrations in groundwater at Landfill 4 are considered to be naturally occurring because the concentrations of TOC upgradient of Landfill 4 are similar to TOC concentrations in shallow groundwater beneath and downgradient of Landfill 4.

The cumulative probability plot for Eh (Figure 7) also indicates that the lower values of Eh begin to form an asymptote at around 100 mV indicating that this is a naturally occurring Eh boundary. If the landfill were influencing Eh, it would be expected to decrease the Eh below zero and as low as negative 200 mV, therefore creating a reducing environment.

The additional data collected during the first three years of monitoring in conjunction with the RI data will be used to verify that the lower Eh conditions are naturally occurring. The assessment will be based on a weight of evidence approach. The weight of evidence approach will take into consideration the following:

- The Eh for the new data and RI data will be plotted on a cumulative probability plot. If the new Eh data plot on either of the upper or lower lines already shown on the plot for the RI data, then they are consistent with the RI data. If the Eh values for the same wells plot on both the upper and lower lines of the cumulative probability plot, this indicates that the landfill is not causing a consistent impact on the Eh of the groundwater.
- If the additional data plotted on the cumulative probability plot confirms the presence of the lower Eh asymptote boundary, then this would add to the weight of evidence that the low Eh values are naturally occurring and have a minimum naturally occurring value. If the new Eh data indicates that the asymptote value is above zero (i.e. oxidizing), then this would also add weight of evidence that the landfill is not impacting the Eh of the groundwater.
- If the TOC concentrations consistently indicate that the TOC concentrations are similar upgradient, beneath, and downgradient of Landfill 4, then the high TOC concentrations can be confirmed to be naturally occurring. TOC concentrations will also be plotted on a cumulative probability plot along with the RI data. If the new TOC concentrations plot on the straight line indicating a single background population, this would add weight of evidence that the TOC concentrations in groundwater are naturally occurring and thus influencing the Eh.
- Other field parameters (temperature, DO, pH and electrical conductivity) will also be evaluated. If these field parameters are consistent with the RI data and indicate a single background population on cumulative probability plots, this would add weight of evidence that the landfill is not impacting the geochemical conditions of the groundwater. During this evaluation, it will be important to take into account the results of the field parameters as a whole and understand that they are not necessarily individually conclusive.
- The concentrations of other compounds which are considered to be indicators of landfill impacts will be evaluated. For example, chloride is typically released and occurs at an elevated concentration if a landfill is impacting the geochemistry of the groundwater beneath the landfill. Trilinear diagrams will be used to establish the relative relationships between the major cations (positively charged ions) and the anions (negatively charged ions). Trilinear diagrams will be used to separate natural changes in groundwater chemistry along groundwater flowpaths from potential landfill impacts on the groundwater chemistry.
- Vertical hydraulic gradient data from the new and existing wells located upgradient, within the landfill footprint and downgradient of the landfill will be used to assess the

potential impacts of deeper groundwater on the geochemistry of the shallow groundwater. An understanding of both horizontal and vertical groundwater flowpaths is important for gaining an understanding of groundwater chemistry interactions between shallow, intermediate and deep groundwater. For example, if an upward groundwater gradient occurs upgradient, beneath and downgradient of the landfill, similar influences on shallow groundwater geochemistry from deep geochemistry could be anticipated. Alternatively, if a downward groundwater gradient occurs upgradient of the landfill and upward gradients occur beneath and downgradient of Landfill 4, the shallow groundwater upgradient of Landfill 4 could be expected to be influenced differently than the shallow groundwater within and downgradient of Landfill 4. During this evaluation, natural changes in groundwater along the groundwater flow path will be taken into account.

- The interaction between groundwater and Crow Creek surface water is also likely influencing groundwater geochemistry and therefore concentrations of iron and manganese in groundwater. This is a potentially significant natural process occurring at Landfill 4 because some reaches of Crow Creek are understood to be recharging the shallow groundwater. In this natural process, the infiltrating surface water moves through a moderately reducing zone within the creek sediments. This decrease in oxidation-reduction potential mobilizes manganese from the sediments resulting in elevated concentrations of manganese in the wells closest to Crow Creek. Therefore, horizontal and vertical hydraulic gradients will be assessed to better understand the relative recharge from Crow Creek surface water to the shallow groundwater versus the recharge from the shallow, intermediate and deep groundwater to Crow Creek surface water. This will provide a better understanding of the potential influence of Crow Creek surface water on groundwater geochemistry downgradient of Landfill 4.

If the weight of evidence is considered sufficient to show that Landfill 4 is not causing a change in Eh and the concentrations of iron and manganese in groundwater are shown to be naturally occurring background concentrations, then the monitoring program can move onto the long-term monitoring outlined in Section 9.0.

If the weight of evidence indicates that iron and manganese concentrations are not naturally occurring and/or that Landfill 4 is causing a change in Eh resulting in a change in iron and manganese concentrations, an assessment of whether an additional investigation and/or a remedial action is necessary to address iron and manganese concentrations in groundwater will be undertaken. The additional investigation may consist of long-term monitoring to assess whether geochemical attenuation of iron and manganese concentrations in groundwater is occurring.

9.0 Step 3: Long-Term Monitoring to Check for Impacts on Groundwater and Surface Water

For the purpose of the FS, a 27 year long-term monitoring (LTM) program is evaluated (total of 30 years including the first three years of quarterly sampling). Five years is the minimum duration of post-closure monitoring for sanitary landfills that ceased receipt of waste before October 9, 1991 (WSWRR Chapter 2, Section 7(q)(vi)). Therefore, after five years of monitoring (3 years of quarterly monitoring and two years of annual monitoring) the data will be reviewed to assess whether it is necessary to continue monitoring. In addition, after

the completion of the first three years of quarterly sampling to address RAO 4 (outlined in Section 6.0), the number of wells, analytical parameters and frequency of sampling will be reviewed. For the purpose of comparing costs, it is assumed that no reduction in sample locations or analyses will occur over the 30 years.

Long-term groundwater and surface water monitoring will assess the concentrations of total and dissolved metals, major cations and anions, VOCs, SVOCs, ammonia, nitrate, nitrite and total Kjeldahl nitrogen, TSS, TDS and TOC in groundwater upgradient and downgradient of Landfill 4 and within Crow Creek. The goal of the long-term monitoring will be to verify that the geochemical conditions of the groundwater are not changing and the landfill is not adversely impacting groundwater quality downgradient of Landfill 4 or within Crow Creek. Groundwater and surface water monitoring data will be compared to groundwater quality data collected during the RI and used to assess trends in the concentrations of compounds in groundwater and surface water. If any upward trends in concentrations of specific compounds are identified in groundwater, these trends will be compared to trends in surface water concentrations to assess if groundwater is contributing contaminants to Crow Creek. Groundwater contaminants will be considered to be contributing to Crow Creek if the concentrations of compounds which show a repeatable and statistically significant increasing trend in concentrations in groundwater also show a repeatable and statistically significant increasing trend in concentrations in surface water adjacent to Landfill 4 compared to surface water upstream of Landfill 4.”

Thirty one (31) monitoring wells, including eight wells located upgradient of Landfill 4, eight wells within the landfill footprint, two wells sidegradient of the landfill, and thirteen wells located downgradient of Landfill 4 are proposed for long-term groundwater monitoring. In addition, four surface water sampling locations (the same locations as those sampled during the RI) are proposed. Figure 2 shows the locations of the proposed groundwater and surface water sampling locations.

Groundwater and surface water samples will be collected on an annual basis during the 27 years following the initial monitoring outlined in Section 6.0. A comprehensive monitoring report will be prepared after 5 years of monitoring to assess the comprehensive data set collected since implementation of the remedy and determine if future monitoring is warranted at Landfill 4.

STEP 1

**Install Deep and
Intermediate Depth
Wells**

STEP 2

**Monitor Groundwater Quality
Quarterly for Three Years to:**

- (a) confirm or reject background of
Fe & Mn**
- (b) resolve uncertainty of landfill
influence on geochemistry**

DECISION 1

**Is Fe & Mn
confirmed as
background?**

No

Yes

DECISION 2

**Is
geochemistry
uncertainty
sufficiently
resolved?**

No

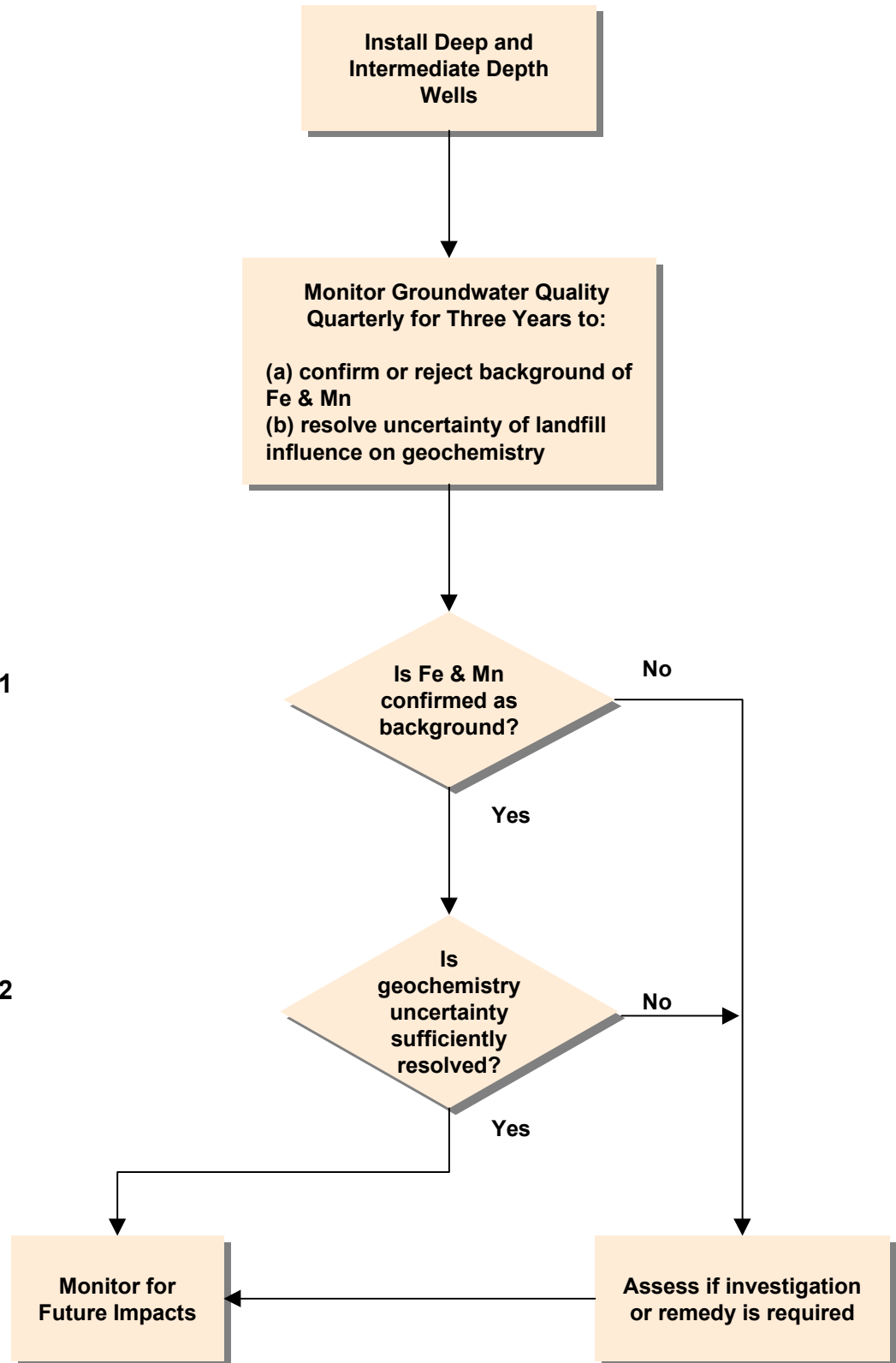
Yes

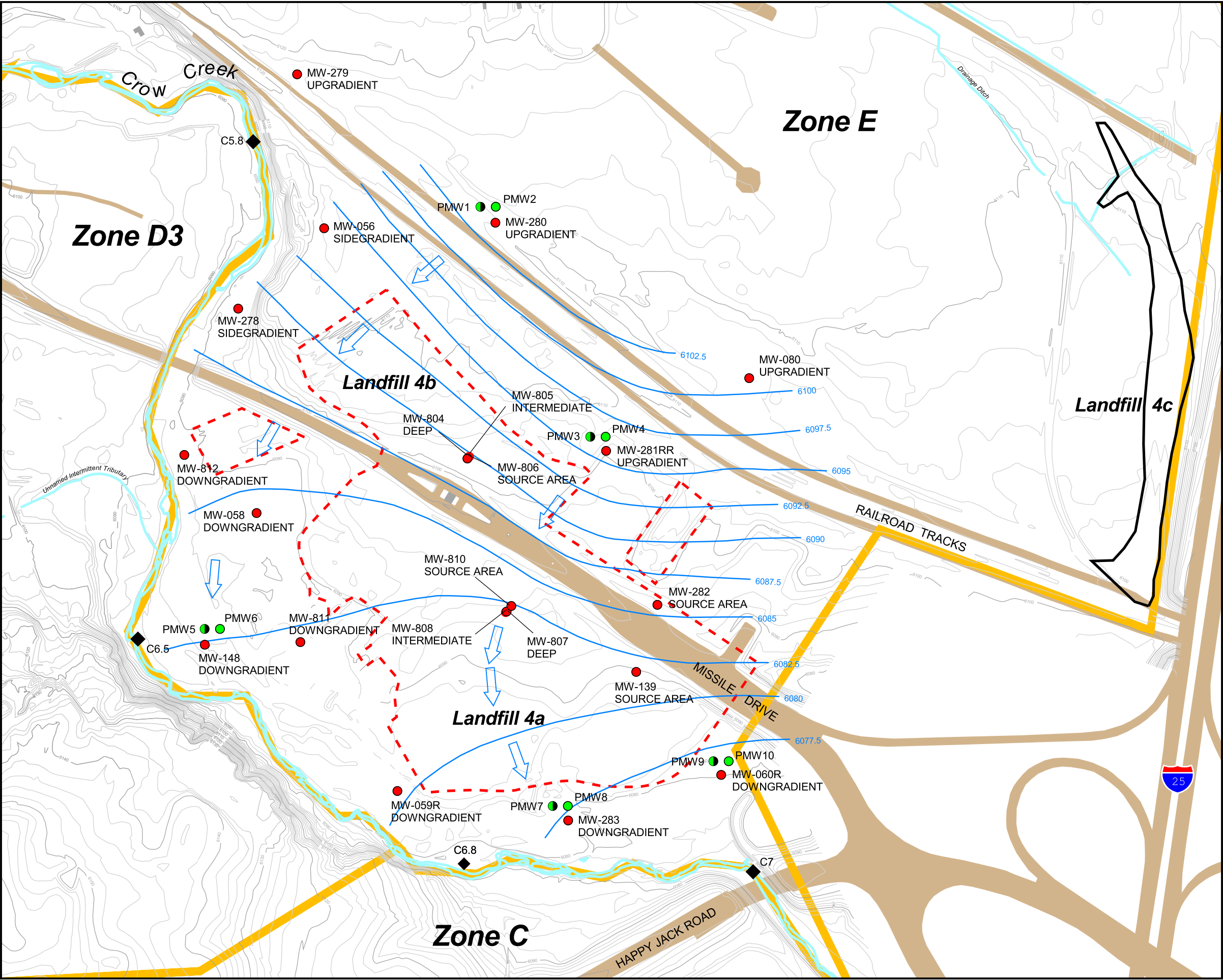
STEP 3

**Monitor for
Future Impacts**

**Assess if investigation
or remedy is required**

FIGURE 1
Landfill 4 Groundwater Monitoring Approach





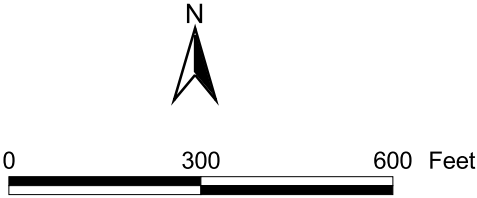
- Legend
- Existing Monitoring Well
 - Proposed New Intermediate Depth Monitoring Well
 - Proposed New Deep Monitoring Well
 - Surface Water Sample
 - Approximate Buried Solid Waste Boundary
 - Approximate IRP Landfill Boundary
 - Groundwater Elevation Contour (1)
 - Groundwater Flow Direction
 - Surface Elevation Contour - 2 ft Interval
 - Surface Elevation Contour - 10 ft Interval
 - Waterway
 - Building
 - Road
 - Base / Zone Boundary

Notes

1. Potentiometric surface is based on 2001 water level measurements.

Source

F. E. Warren AFB Environmental Restoration Program
CH2M HILL



Horizontal Datum: NAD 83
Vertical Datum: NAVD 88

Figure 2
Existing and Proposed
New Groundwater Monitoring Well
and Surface Water Sampling Locations

F. E. Warren AFB
Landfill 4 Feasibility Study

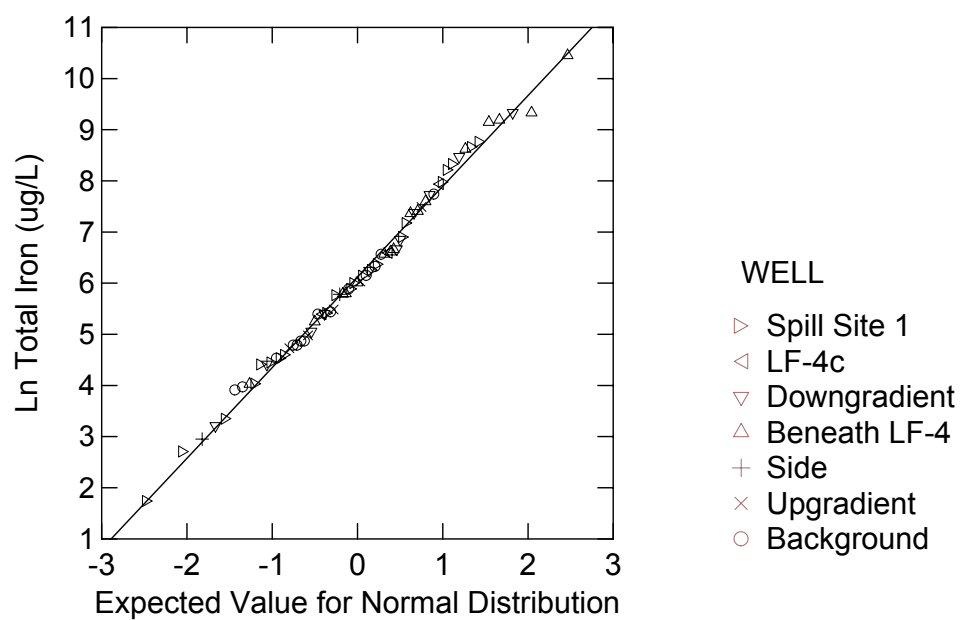


Figure 3. Probability plot for total iron in groundwater at FE Warren AFB.

Note: The linear least square fit line of all 73 points has a correlation coefficient $r=0.98$ accounting for 96 percent of the total iron variance.

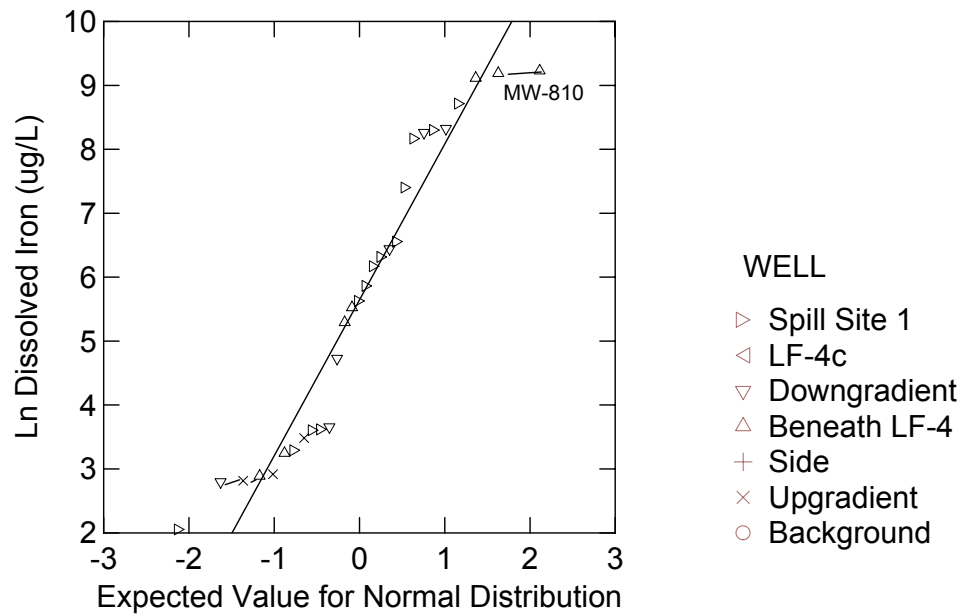


Figure 4. Probability plot for dissolved iron in groundwater from FE Warren AFB.

Note: The linear least square fit line for all 29 points has a correlation coefficient, $r=0.99$ accounting for 98 percent of the dissolved iron variance.

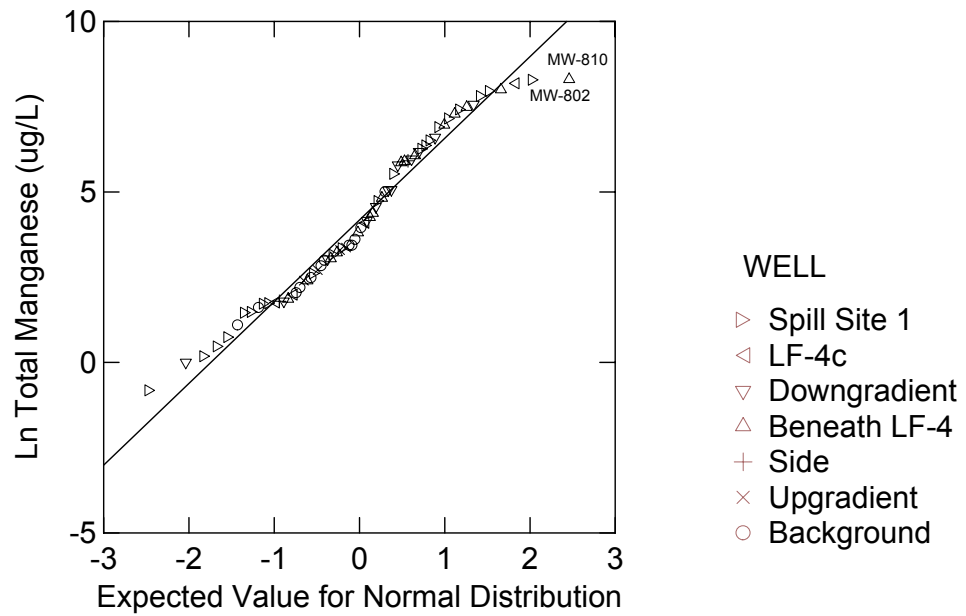


Figure 5. Probability plot for total manganese in groundwater from FE Warren AFB.

Note: The linear least square fit line for all 72 points has a correlation coefficient, $r = 0.99$ accounting for 99 percent of the total manganese variance.

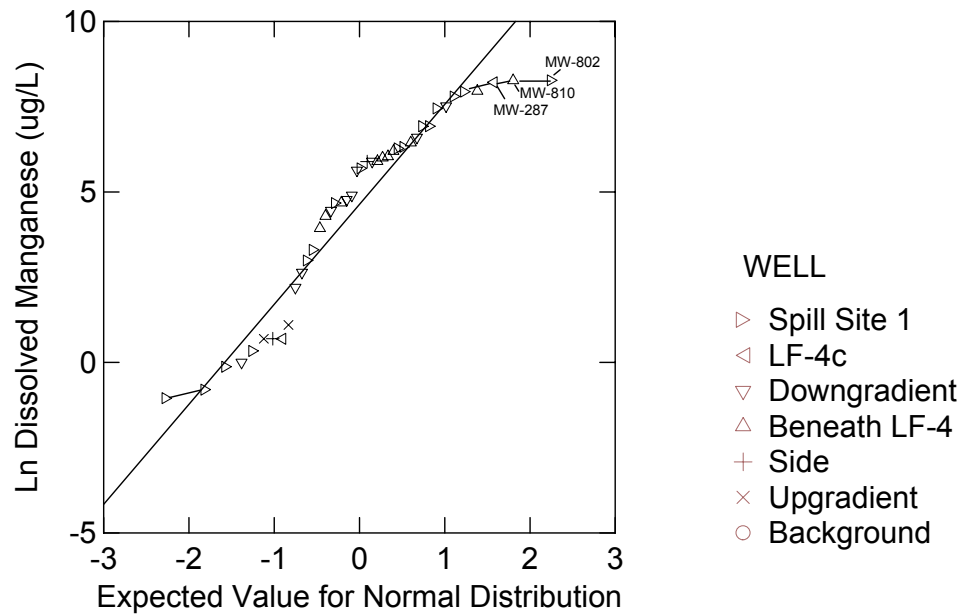


Figure 6. Probability plot for the dissolved manganese in groundwater from FE Warren AFB.

Note: The linear least square fit line for all 42 points has a correlation coefficient $r=0.97$ accounting for 94 percent of the dissolved manganese variance.

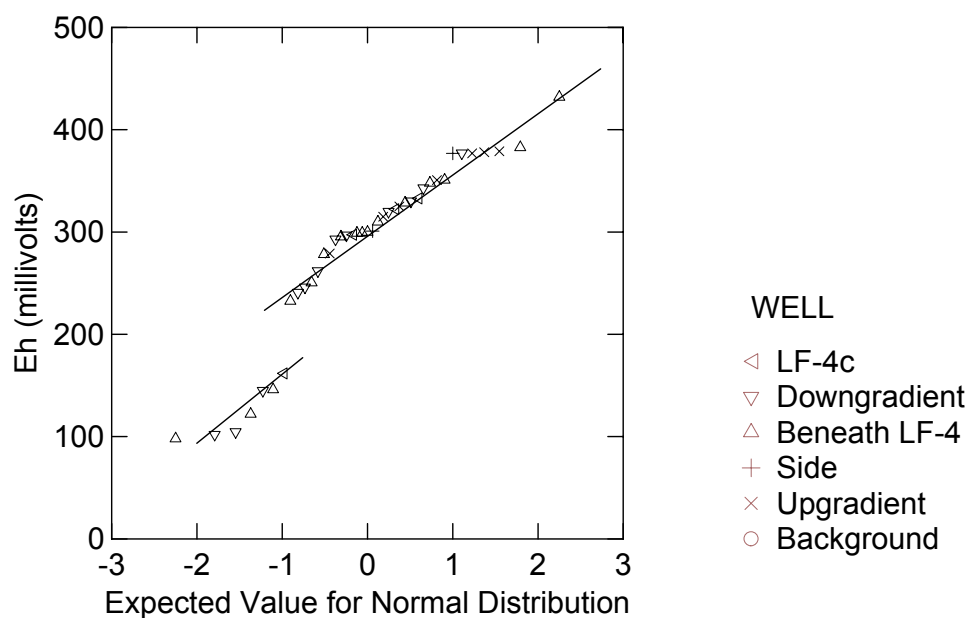


Figure 7. Probability plots for the oxidation-reduction potential, Eh, of groundwater from FE Warren AFB.

Note: The upper, more oxidized, linear least square fit line for 34 points has a correlation coefficient $r=0.98$ accounting for 95 percent of the Eh variance. The lower, less oxidized, linear least square fit line for 7 points has a correlation coefficient of 0.97 accounting for 94 percent of the Eh variance for these points.

COMPARISON OF TOTAL COST OF REMEDIAL ACTION ALTERNATIVES FOR LANDFILL 4

Site:	F.E. Warren Air Force Base	Base Year:	2003
Location:	Zone E, Landfill 4	Date:	9/24/2003
Phase:	Feasibility Study		

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
	No Action	Institutional Controls	Localized Site Improvements	Engineered Landfill Cap	Excavation and Removal
Total Project Duration (Years)	0	30	30	30	30
Capital Cost	\$0	\$80,000	\$1,950,000	\$4,730,000	\$8,200,000
Operations and Maintenance Cost	\$0	\$60,000	\$5,118,500	\$5,151,000	\$3,006,000
Total Present Value of Alternative	\$0	\$110,000	\$4,900,000	\$7,700,000	\$9,900,000

Alternative 2 Institutional Controls			COST ESTIMATE SUMMARY			
Site:	F.E. Warren Air Force Base		Description: Alternative 2 consists of institutional controls to limit access and future development at Landfill 4. Groundwater will be monitored for up to thirty (30) years following implementation of this alternative.			
Location:	Zone E, Landfill 4					
Phase:	Feasibility Study					
Base Year:	2003					
Date:	9/24/2003					
CAPITAL COSTS						
DESCRIPTION		QTY	UNIT	UNIT COST	TOTAL	NOTES
Institutional Controls						
Include institutional controls in Base General Plan		1	LS	\$10,000	\$10,000	
Warning signs at site entrances		10	EA	\$200	\$2,000	
SUBTOTAL					\$ 12,000.00	
Other Costs						
Site boundary survey		1	LS	\$30,000	\$30,000	
SUBTOTAL					\$30,000	
Contingency		25%		\$42,000	\$10,500	10% Scope + 15% Bid
SUBTOTAL					\$52,500	
Project management		10%		\$52,500	\$5,250	USEPA 2000, p. 5-13, <\$100K
Remedial design workplan		20%		\$52,500	\$10,500	USEPA 2000, p. 5-13, <\$100K
Documentation of Closure Activities		1	LS	\$10,000	\$10,000	ROM estimate
SUBTOTAL					\$25,750	
TOTAL CAPITAL COST					\$80,000	
OPERATIONS AND MAINTENANCE COST						
DESCRIPTION		QTY	UNIT	UNIT COST	TOTAL	NOTES
Year 1-30						
Semi-annual Inspection and Reporting		60	ea	\$800	\$48,000	
SUBTOTAL					\$48,000	
Contingency		25%			\$12,000	
TOTAL O&M COST					\$60,000	
PRESENT VALUE ANALYSIS						
YEAR	COST TYPE	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR ² (5.0%)	PRESENT VALUE	NOTES
0	CAPITAL COST	\$80,000	\$80,000	1.000	\$80,000	
1-30	ANNUAL O&M COST, YEARS 1-30	\$60,000	\$2,000	14.640	\$29,281	
		\$140,000			\$109,281	
TOTAL PRESENT VALUE OF ALTERNATIVE					\$110,000	
SOURCE INFORMATION						
1. United States Environmental Protection Agency. July 2000. A Guide to Preparing and Documenting Cost Estimates During the Feasibility Study. EPA 540-R-00-002. (USEPA, 2000).						
2. Discount factor of 5.0% is used for F.E. Warren Air Force Base. Each discount factor for the annual series is calculated by multiplying the (P/A) discount factor using a 5.0% discount rate and the (P/F) discount factor using a 5.0 discount rate, with each discount factor applied over the associated number of years.						

Alternative 3

Localized Site Improvements

Site: F.E. Warren Air Force Base

Location: Zone E, Landfill 4

Phase: Feasibility Study

Base Year: 2003

Date: 9/24/2003

Description: Alternative 3 consists of addressing specific areas of Landfill 4 which do not meet RAOs. Site improvements will include surface controls to re-establish positive drainage across the site, excavation and removal activities, and site restoration. Wastes designated for disposal will be transported to an off-base disposal facility.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Institutional Controls					
Include institutional controls in Base General Plan	1	LS	\$10,000	\$10,000	
Warning signs at site entrances	10	EA	\$200	\$2,000	
SUBTOTAL				\$12,000	
Surface Controls					
Compacted clay fill	6,000	CY	\$17.37	\$104,220	
Regrading activities	24,200	SY	\$0.57	\$13,794	assume up to 5 acres to be regraded
SUBTOTAL				\$118,014	
Excavation and removal					
<u>Buried Solid Wastes (Unburned Materials)</u>					assume non-hazardous wastes
Excavate Cover/Temporarily Stockpile	9,000	CY	\$2.50	\$22,500	
Excavate and load Wastes	14,000	CY	\$2.50	\$35,000	
Replace cover	9,000	CY	\$2.50	\$22,500	
Transport to off-site disposal facility	700	trip	\$275	\$192,500	assume 80 mile roundtrip, 20 CY Truck
Waste disposal fee (non-hazardous wastes)	13,300	CY	\$11.25	\$149,625	assumed that 95% of material is non-haz
Waste disposal fee (hazardous wastes)	700	CY	\$190	\$133,000	assumed that 5% of material is hazardous
Waste characterization	7	EA	\$2,000	\$14,000	assume 1 per 2,000 CY
UXO Support during excavation	13	Days	\$1,200	\$15,960	assume 1,000 CY/day excavated
<u>Surficial Concrete and Demolition Debris</u>					
Excavate and load	12,000	CY	\$2.50	\$30,000	
Transport to off-site disposal facility	600	trip	\$275.00	\$165,000	assume 80 mile roundtrip, 20 CY Truck
Waste disposal fee (Concrete)	11,000	CY	\$12.50	\$137,500	
Waste disposal fee (abestos-containing demo debris)	1,000	CY	\$18	\$18,000	
SUBTOTAL				\$935,585	
Surface Restoration					
Site Debris Clean Up & Removal	28	ACRE	\$276	\$7,724	assume entire site cleaned
Revegetation	10	ACRE	\$1,750	\$17,500	assume up to 10 acres disturbed
Well Installation	10	EA	\$2,500	\$25,000	
Site Boundary Survey	1	LS	\$30,000	\$30,000	
SUBTOTAL				\$80,224	
Contingency	25%		\$1,145,823	\$286,456	10% Scope + 15% Bid
SUBTOTAL				\$1,432,278	
Mobilization/Demobilization	7%		\$1,432,278	\$100,259	
Project Management	6%		\$1,432,278	\$85,937	USEPA 2000, p. 5-13, \$500K - \$2M
Project Workplan, Site Survey, and Design	12%		\$1,432,278	\$171,873	USEPA 2000, p. 5-13, \$500K - \$2M
Construction Management	8%		\$1,432,278	\$114,582	USEPA 2000, p. 5-13, \$500K - \$2M
Closure Report	1	LS	\$50,000	\$50,000	ROM est./Document Const. Work
SUBTOTAL				\$522,652	
TOTAL CAPITAL COST				\$1,950,000	

OPERATIONS AND MAINTENANCE COST

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Year 1-3					
Quarterly Inspection and Reporting	12	ea	\$800	\$9,600	1 person at \$100/hr for 8 hrs
Repairs (reseeding, fill)	3	ea	\$2,000	\$6,000	<0.5 acres/year, 1 day event
Quarterly Groundwater/Surface Water Monitoring	12	event	\$87,000	\$1,044,000	See attached Worksheet 2
Annual Monitoring Report	3	ea	\$20,000	\$60,000	ROM estimate w/ 4 quarters data
SUBTOTAL				\$1,119,600	
Contingency	25%			\$279,900	10% Scope + 15% Bid
SUBTOTAL				\$1,399,500	
Years 4-30					
Semi-Annual Inspection and Reporting	54	ea	\$800	\$43,200	1 person at \$100/hr for 8 hrs
Repairs (reseeding, fill)	14	ea	\$2,000	\$28,000	<0.5 acres/year, 1 day event
Annual Groundwater/Surface Water Monitoring	27	event	\$87,000	\$2,349,000	See attached Worksheet 2
Annual Monitoring Report	27	ea	\$15,000	\$405,000	ROM estimate annual data
Comprehensive Data Assessment	6	ea	\$25,000	\$150,000	For groundwater/surface water data
SUBTOTAL				\$2,975,200	
Contingency	25%			\$743,800	10% Scope + 15% Bid
SUBTOTAL				\$3,719,000	
TOTAL O&M COST				\$5,118,500	

Alternative 3 Localized Site Improvements

Site: F.E. Warren Air Force Base

Location: Zone E, Landfill 4

Phase: Feasibility Study

Base Year: 2003

Date: 9/24/2003

Description: Alternative 3 consists of addressing specific areas of Landfill 4 which do not meet RAOs. Site improvements will include surface controls to re-establish positive drainage across the site, excavation and removal activities, and site restoration. Wastes designated for disposal will be transported to an off-base disposal facility.

PRESENT VALUE ANALYSIS

YEAR	COST TYPE	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR ² (5.0%)	PRESENT VALUE	NOTES
0	CAPITAL COST	\$1,950,000	\$1,950,000	1.000	\$1,950,000	
1-3	ANNUAL O&M COST, YEAR 1-3	\$1,399,500	\$466,500	2.594	\$1,209,900	
4-30	ANNUAL O&M COST, YEARS 4-30	<u>\$3,719,000</u>	\$137,741	12.649	<u>\$1,742,311</u>	
		\$7,068,500			\$4,902,211	
TOTAL PRESENT VALUE OF ALTERNATIVE					\$4,900,000	

SOURCE INFORMATION

1. United States Environmental Protection Agency. July 2000. A Guide to Preparing and Documenting Cost Estimates During the Feasibility Study. EPA 540-R-00-002. (USEPA, 2000).
2. Discount factor of 5.0% is used for F.E. Warren Air Force Base. Each discount factor for the annual series is calculated by multiplying the (P/A) discount factor using a 5.0% discount rate and the (P/F) discount factor using a 5.0 discount rate, with each discount factor applied over the associated number of years.

Alternative 4 Engineered Landfill Cap

COST ESTIMATE SUMMARY

Site: F.E. Warren Air Force Base
Location: Zone E, Landfill 4
Phase: Feasibility Study
Base Year: 2003
Date: 9/24/2003

Description: Alternative 4 consists of site clearing, waste consolidation installation of a municipal landfill cap, and site restoration .

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Institutional Controls					
Include institutional controls in Base General Plan	1	LS	\$10,000	\$10,000	
Warning signs at site entrances	10	EA	\$200	\$2,000	
SUBTOTAL				\$12,000	
Site Preparation					
Clearing/Grubbing	28	AC	\$1,000	\$28,000	assumes 28 acres disturbed at site
Well Installation	10	EA	\$2,500	\$25,000	
SUBTOTAL				\$53,000	
Waste Consolidation					
Excavation	24,000	CY	\$2.50	\$60,000	
Load and Consolidate Wastes under Landfill Cap	24,000	CY	\$2.50	\$60,000	
UXO Support during consolidation activities	25	Days	\$1,200	\$30,000	assume 1,000 CY/day excavated
SUBTOTAL				\$150,000	
Landfill Cap					
Imported Soil Fill	79,000	CY	\$10.55	\$833,450	includes using concrete/demo/waste consolidated as fill
Surface re-grading	111,000	SY	\$0.57	\$63,270	assumes 16 acre cap for 4a and 7 acre cap for 4b
Infiltration Barrier (2-feet of compacted soil)	74,000	CY	\$17.37	\$1,285,380	Landfill cap will encompass approx. 23 acres
Topsoil Cover (6-inches thick)	19,000	CY	\$24.45	\$464,550	Landfill cap will encompass approx. 23 acres
SUBTOTAL				\$2,646,650	
Surface Restoration					
Revegetation	28	ACRE	\$1,750	\$49,000	assumes 28 acres disturbed at site
Site boundary survey	1	LS	\$30,000	\$30,000	
SUBTOTAL				\$79,000	
Contingency	25%		\$2,940,650	\$735,163	10% Scope + 15% Bid
SUBTOTAL				\$3,675,813	
Mobilization/Demobilization	7%		\$3,675,813	\$257,307	
Project Management	5%		\$3,675,813	\$183,791	USEPA 2000, p. 5-13, \$2M-\$10M
Project Workplan, Site Survey, and Design	8%		\$3,675,813	\$294,065	USEPA 2000, p. 5-13, \$2M-\$10M
Construction Management	6%		\$3,675,813	\$220,549	USEPA 2000, p. 5-13, \$2M-\$10M
Closure Report	1	LS	\$100,000	\$100,000	Document Const. Work, QA/QC, and Record DWGs
SUBTOTAL				\$1,055,711	
TOTAL CAPITAL COST				\$4,730,000	

Alternative 4 Engineered Landfill Cap

COST ESTIMATE SUMMARY

Site: F.E. Warren Air Force Base
Location: Zone E, Landfill 4
Phase: Feasibility Study
Base Year: 2003
Date: 9/24/2003

Description: Alternative 4 consists of site clearing, waste consolidation installation of a municipal landfill cap, and site restoration .

OPERATIONS AND MAINTENANCE COST

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Year 1-3					
Quarterly Inspection and Reporting	12	ea	\$800	\$9,600	1 person at \$100/hr for 8 hrs
Repairs (reseeding, fill)	3	ea	\$2,000	\$6,000	
Quarterly Groundwater/Surface Water Monitoring	12	event	\$87,000	\$1,044,000	See attached Worksheet 2
Annual Monitoring Report	3	ea	\$20,000	\$60,000	ROM estimate w/ 4 quarters data
SUBTOTAL				\$1,119,600	
Contingency	25%			\$279,900	10% Scope + 15% Bid
SUBTOTAL				\$1,399,500	
Years 4-30					
Semi-Annual Inspection	54	ea	\$800	\$43,200	1 person at \$100/hr for 8 hrs
Repairs (reseeding, fill)	27	ea	\$2,000	\$54,000	<0.5 acres/year, 1 day event
Annual Groundwater/Surface Water Monitoring	27	event	\$87,000	\$2,349,000	See attached Worksheet 2
Annual Monitoring Report	27	ea	\$15,000	\$405,000	ROM estimate w/ annual data
Comprehensive Data Assessment	6	ea	\$25,000	\$150,000	For groundwater/surface water data
SUBTOTAL				\$3,001,200	
Contingency	25%			\$750,300	10% Scope + 15% Bid
SUBTOTAL				\$3,751,500	
TOTAL O&M COST				\$5,151,000	

PRESENT VALUE ANALYSIS

YEAR	COST TYPE	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR ² (5.0%)	PRESENT VALUE	NOTES
0	CAPITAL COST	\$4,730,000	\$4,730,000	1.000	\$4,730,000	
1-3	ANNUAL O&M COST, YEAR 1-3	\$1,399,500	\$466,500	2.594	\$1,209,900	
4-30	ANNUAL O&M COST, YEARS 4-30	<u>\$3,751,500</u>	<u>\$138,944</u>	<u>12.649</u>	<u>\$1,757,536</u>	
		\$9,881,000			\$7,697,437	
TOTAL PRESENT VALUE OF ALTERNATIVE					\$7,700,000	

SOURCE INFORMATION

- United States Environmental Protection Agency. July 2000. A Guide to Preparing and Documenting Cost Estimates During the Feasibility Study. EPA 540-R-00-002. (USEPA, 2000).
- Discount factor of 5.0% is used for F.E. Warren Air Force Base. Each discount factor for the annual series is calculated by multiplying the (P/A) discount factor using a 5.0% discount rate and the (P/F) discount factor using a 5.0 discount rate, with each discount factor applied over the associated number of years.

Alternative 5			COST ESTIMATE SUMMARY				
Full Removal of Waste with Off-Site Waste Disposal							
Site:	F.E. Warren Air Force Base		Description: Alternative 5 consists of complete removal of buried and surficial wastes. Existing cover soils will be re-used to restore the site grades. Disturbed areas will be restored and revegetated. Wastes designated for disposal will be transported to an off-base disposal facility.				
Location:	Zone E, Landfill 4						
Phase:	Feasibility Study						
Base Year:	2003						
Date:	9/24/2003						
CAPITAL COSTS							
DESCRIPTION			QTY	UNIT	UNIT COST	TOTAL	NOTES
Institutional Controls							
Include institutional controls in Base General Plan			1	LS	\$10,000	\$10,000	
Warning signs at site entrances			10	EA	\$200	\$2,000	
SUBTOTAL						\$12,000	
Site Preparation							
Clearing/Grubbing			28	AC	\$276	\$7,724	assume entire site
Well abandonment			9	EA	\$1,000	\$9,000	
SUBTOTAL						\$16,724	
Excavation and Disposal							
Buried Solid Wastes							
Excavate cover/temporarily stockpile			190,000	CY	\$2.50	\$475,000	
Excavate and load solid wastes			110,000	CY	\$2.50	\$275,000	assume non-hazardous
Transport wastes to off-site disposal facility			5,500	Trip	\$275	\$1,512,500	assume 80 mile roundtrip, 20 CY truck
Waste disposal fee (non-hazardous wastes)			104,500	CY	\$11.25	\$1,175,625	assumed that 95% of material is non-haz
Waste disposal fee (hazardous wastes)			5,500	CY	\$190	\$1,045,000	assumed that 5% of material is hazardous
Waste characterization (1 per 2,000 CY)			52	EA	\$2,000	\$104,500	
UXO Support during excavation			300	Days	\$1,200	\$360,000	assume 1,000 CY/day excavated
Surficial Concrete and Demolition Debris							
Excavate and load			12,000	CY	\$2.50	\$30,000	
Transport to off-site disposal facility			600	Trip	\$275	\$165,000	assume 80 mile roundtrip, 20 CY truck
Waste disposal fee (Concrete)			11,000	CY	\$ 12.50	\$137,500	
Waste disposal fee (abestos-containing demo debris)			1,000	CY	\$18	\$18,000	
Verification Sampling of subsoils			28	AC	\$1,000	\$28,000	Assume one verification sample per acre
SUBTOTAL						\$5,326,125	
Surface Restoration							
Site Regrading			135,520	SY	\$0.57	\$77,246	
Revegetation			28	AC	\$1,750	\$49,000	
Site Boundary Survey			1	LS	\$30,000	\$30,000	
SUBTOTAL						\$156,246	
Contingency			25%		\$5,511,095	\$1,377,774	10% Scope + 15% Bid
SUBTOTAL						\$6,888,869	
Mobilization/Demobilization			7%		\$6,888,869	\$482,221	
Project Management			5%		\$6,888,869	\$344,443	USEPA 2000, p. 5-13, \$2M-\$10M
Project Workplan and Design			8%		\$6,888,869	\$551,109	USEPA 2000, p. 5-13, \$2M-\$10M
Construction Management			6%		\$6,888,869	\$413,332	USEPA 2000, p. 5-13, \$2M-\$10M
Closure Report			1	LS	\$100,000	\$100,000	Document Const. Work, QA/QC, and Record DWGs
SUBTOTAL						\$1,308,885	
TOTAL CAPITAL COST						\$8,200,000	

Alternative 5 Full Removal of Waste with Off-Site Waste Disposal				COST ESTIMATE SUMMARY									
Site: Location: Phase: Base Year: Date:	F.E. Warren Air Force Base Zone E, Landfill 4 Feasibility Study 2003 9/24/2003	Description: Alternative 5 consists of complete removal of buried and surficial wastes. Existing cover soils will be re-used to restore the site grades. Disturbed areas will be restored and revegetated. Wastes designated for disposal will be transported to an off-base disposal facility.											
OPERATIONS AND MAINTENANCE COST													
<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 40%;">DESCRIPTION</th> <th style="width: 10%;">QTY</th> <th style="width: 10%;">UNIT</th> <th style="width: 10%;">UNIT COST</th> <th style="width: 10%;">TOTAL</th> <th style="width: 20%;">NOTES</th> </tr> </thead> </table>							DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES	
DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES								
Year 1-3													
Quarterly Inspection and Reporting	12	ea	\$800	\$9,600	1 person at \$100/hr for 8 hrs								
Repairs (reseeding, fill)	3	ea	\$2,000	\$6,000									
Quarterly Groundwater/Surface Water Monitoring	12	event	\$43,000	\$516,000	See attached Worksheet 3								
Annual Monitoring Report	3	ea	\$20,000	\$60,000	ROM estimate w/ 4 quarters data								
SUBTOTAL				\$591,600									
Contingency	25%			\$147,900	10% Scope + 15% Bid								
SUBTOTAL				\$739,500									
Years 4-30													
Semi-Annual Inspection	54	ea	\$800	\$43,200	1 person at \$100/hr for 8 hrs								
Repairs (reseeding, fill)	27	ea	\$2,000	\$54,000	<0.5 acres/year, 1 day event								
Annual Groundwater/Surface Water Monitoring	27	event	\$43,000	\$1,161,000	See attached Worksheet 3								
Annual Monitoring Report	27	ea	\$15,000	\$405,000	ROM estimate w/ annual data								
Comprehensive Data Assessment	6	ea	\$25,000	\$150,000	For groundwater/surface water data								
SUBTOTAL				\$1,813,200									
Contingency	25%			\$453,300	10% Scope + 15% Bid								
SUBTOTAL				\$2,266,500									
TOTAL O&M COST				\$3,006,000									
PRESENT VALUE ANALYSIS													
<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">YEAR</th> <th style="width: 30%;">COST TYPE</th> <th style="width: 15%;">TOTAL COST</th> <th style="width: 15%;">TOTAL COST PER YEAR</th> <th style="width: 10%;">DISCOUNT FACTOR² (5.0%)</th> <th style="width: 10%;">PRESENT VALUE</th> <th style="width: 20%;">NOTES</th> </tr> </thead> </table>							YEAR	COST TYPE	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR ² (5.0%)	PRESENT VALUE	NOTES
YEAR	COST TYPE	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR ² (5.0%)	PRESENT VALUE	NOTES							
0	CAPITAL COST	\$8,200,000	\$8,200,000	1.000	\$8,200,000								
1-3	ANNUAL O&M COST, YEAR 1-3	\$739,500	\$246,500	2.594	\$639,315								
4-30	ANNUAL O&M COST, YEARS 4-30	\$2,266,500	\$83,944	12.649	\$1,061,830								
		\$11,206,000			\$9,901,145								
TOTAL PRESENT VALUE OF ALTERNATIVE					\$9,900,000								
SOURCE INFORMATION													
1. United States Environmental Protection Agency. July 2000. A Guide to Preparing and Documenting Cost Estimates During the Feasibility Study. EPA 540-R-00-002. (USEPA, 2000). 2. Discount factor of 5.0% is used for F.E. Warren Air Force Base. Each discount factor for the annual series is calculated by multiplying the (P/A) discount factor using a 5.0% discount rate and the (P/F) discount factor using a 5.0 discount rate, with each discount factor applied over the associated number of years.													

Individual Unit Cost Summary
Feasibility Study for Landfill 4
F.E. Warren AFB, Wyoming

Cost Worksheet 1 - Individual Unit Cost Line Items

Item	Unit Cost	Units	References
Institutional Control Items			
Institutional controls in Base General Plan	\$10,000	LS	Eng. Estimate
Warning Signs	\$200	EA	Eng. Estimate
Site Preparation			
Clearing/Grubbing	\$1,000	AC	Eng. Estimate
Site Debris Clean Up & Removal	\$276	AC	RSM 017140300
Well abandonment	\$1,000	EA	Eng. Estimate
Well Installation	\$2,500	EA	Eng. Estimate
Earthwork Items			
Site Work			
Excavate and Temporarily Stockpile Onsite	\$2.50	CY	
Excavate and load	\$2.50	CY	
Surface Grading	\$0.57	SY	RSM 023104400100
Fill and Borrow			
Unclassified Fill, Delivered, Offsite Source, Placed	\$10.55	CY	RSM 01730423 adjusted for 6-mile haul/2.1 cycles per hour at \$2.65 CY RSM01703022340545
Topsoil, Delivered, Offsite Source, Placed	\$24.45	CY	RSM 018050301
Compacted Clay, 6-inch lifts, Offsite Source, Placed	\$17.37	CY	RSM 033080506, 6-mile haul/2.1 cycles per hour
Waste Disposal Items			
Waste Characterization	\$2,000	EA	Lab Estimate for TCLP (VOA, SVOA, Pesticides/Herbicides, Metals)
Non-hazardous waste disposal fee	\$ 11.25	CY	Bid from Waste Management, N. Weld Cnty Landfill, July 2002
Hazardous Waste transportation and disposal fee	\$ 190	CY	Verbal Quote from Waste Management, May 2003 (\$260/ton)
C&D waste disposal fee	\$ 12.50	CY	Bid from Waste Management, N. Weld Cnty Landfill, July 2002
Waste disposal fee (abestos containing material)	\$ 18.00	CY	Verbal Quote from Waste Management, May 2003
Transport Wastes, Bulk Transport, 20 CY haul	\$275	trip	Verbal estimate from Domino construction. Based on 80 mile/2hr roundtrip, 20 CY end dump truck, 80 miles round trip, 2 hours.
Site Restoration Items			
Revegetation			
Mechanical Seeding and Mulching	\$1,500	AC	Pawnee Buttes Seed Co. Greeley, CO \$1,000 to 1,500 per acre, 970-356-7002, 10/16/02
Seed	\$250	AC	Pawnee Buttes Seed Co. Greeley, CO \$50 to \$250 per acre, 970-356-7002, 10/16/02
	\$1,750		
Site Survey	\$30,000	LS	
Long Term Monitoring Items			
Annual report w/ quarterly data	\$20,000	EA	Eng. Estimate
Annual Report w/ Annual data	\$15,000	EA	Eng. Estimate
Annual Report w/annual data	\$10,000	EA	Eng. Estimate
Comprehensive Site Data Assessment (GW/SW)	\$25,000	EA	Eng. Estimate
Annual Report - Site Inspections only	\$2,500	EA	Eng. Estimate
Site Inspection	\$800	EA	Eng. Estimate
Site Repairs	\$2,000	EA	assumes 2 people, one day, \$100/hr, one full dump truck of clean soil, one Bobcat
Other Items			
UXO Support	\$1,200	day	ROM est. from EOTI for Zone E Trenching Investigation, 2000.

Cost Worksheet 2 - Groundwater and Surface Water Sampling - Alternatives 2, 3, and 4

Item	Unit Cost	Units	References
Mobilize / Gather field equipment/Demobilize	\$2,400	event	assume 1 person, 3 days, \$100/hr
Equipment purchase/rental	\$1,000	event	Eng. Estimate
Sample wells	\$18,000		assume 2 people, 10 hours/day, \$100/hr, 4 samples per day = 35/4 = 9 days
Analytical Costs			
Well/Surface Water Sampling	\$40,250	event	assume 31 well/4 SW locations. \$1150 per sample for VOC,SVOCs, metals (tot/dis), anions/cations, Nitrogen(s), TDS,TSS, TOC
Duplicate Sample	\$3,450	event	assume 3 duplicate sample at \$1150
Equipment Blank	\$2,300	event	assume 2 equipment blank at \$1150
Matrix Spike/Matrix Spike Duplicate	\$6,900	event	assume 6 samples (1 MS/1MSD) at \$1150
Travel Blank	\$990	event	assume 9 trip blanks for VOCs only
Ambient Blanks	1-30	event	assume 2 ambient blanks for VOCs only
shipping costs	\$1,350	event	assume 2 wells per cooler, \$75 per cooler
Validate data/prepare report/ERPIMS submittal	\$8,000	event	Assume 5 days to validate, 1 day for report, 2 days for ERPIMS submittal at \$100/hr
Travel Costs	\$2,450	event	Assume 10 days, per diem at \$90/day/person, rental van at \$65/day
	\$87,090		Per Groundwater Sampling Event
	\$87,000		Rounded To Nearest \$1k

Individual Unit Cost Summary

Feasibility Study for Landfill 4

*F.E. Warren AFB, Wyoming***Cost Worksheet 3 - Groundwater and Surface Water Sampling - Alternative 5**

Item	Unit Cost	Units	References
Mobilize / Gather field equipment/Demobilize	\$2,400	event	assume 1 person, 3 days, \$100/hr
Equipment purchase/rental	\$1,000	event	Eng. Estimate
Sample wells	\$8,000	event	assume 2 people, 10 hours/day, \$100/hr, 4 samples per day = 14/4 = 4 days
<u>Analytical Costs</u>			
Well/Surface Water Sampling	\$16,100	event	assume 10 well/4 SW locations. \$1150 per sample for VOC,SVOCs, metals (tot/dis), anions/cations, Nitrogen(s), TDS,TSS, TOC
Duplicate Sample	\$2,300	event	assume 2 duplicate samples at \$1150
Equipment Blank	\$2,300	event	assume 2 equipment blank at \$1150
Matrix Spike/Matrix Spike Duplicate	\$4,600	event	assume 4 samples (1 MS/1MSD) at \$1150
Travel Blank	\$440	event	assume 4 trip blanks for VOCs only
Ambient Blanks	\$220	event	assume 2 ambient blanks for VOCs only
shipping costs	\$600	event	assume 2 wells per cooler, \$75 per cooler
Validate data/prepare report/ERPIMS submittal	\$3,000	event	Assume 3 days to validate, 1 day for report, 2 days for ERPIMS submittal at \$100/hr
Travel Costs	\$2,450	event	Assume 10 days, per diem at \$90/day/person, rental van at \$65/day
	\$43,410	Per Groundwater Sampling Event	
	\$43,000	Rounded To Nearest \$1k	

Response to Comments

WDEQ Comments on

Draft Final Feasibility Study Landfill 4, Zone E, Operable Unit 12

General Comments

1. In general there is a lack of balance in this document when referring to information previously presented in the RI regarding metals. Remove all references such as "WDEQ and EPA will confirm" and replace with "WDEQ and EPA will review and confirm or reject." We do not agree to confirm background concentrations prior to data review and confirmation from EPA toxicologist/statistician. That data still needs to be collected and subsequent statistical analyses need to be determined to be acceptable.

Response: References as stated above were not located within the FS. However, the USAF recognizes that additional data needs to be collected to reduce the uncertainty associated with the concentrations of iron and manganese in groundwater, therefore the monitoring plan (contained in Appendix B) will be fully developed during the design phase. The refined and fully developed monitoring plan will outline the additional data to be collected and how the data will be used to assess whether iron and manganese concentrations are background concentrations or not.

Specific Comments

2. Wyoming Department of Environmental Quality comments appear to be included with EPA comments as numbers 41 to 44. For comments and responses to be readily accessible, WDEQ comments need to be presented in a separate section under a heading separate from the EPA comments.

Response: WDEQ comments have been separated from EPA comments under a separate section and separate heading and numbering.

3. The state does not agree that background concentrations have been defined. The state also does not agree to confirm background concentrations prior to reviewing data. After reviewing data in the future, we will concur or we will refute. The following RAO implies that we already concur.

Page 2-1, Section 2.2.1 Remedial Action Objectives, bullet number 4, states, "The background concentrations defined in the RI are to be confirmed through future

monitoring.” Replace this with the flexible RAO agreed to by EPA and WDEQ: “Background concentrations are best evaluated through future monitoring to address temporal and spatial variations.”

Response: RAO 4 has been modified on pages ES-2, 2-1, and B-2 to: “Restore ground water to beneficial use, which in this case is restoration of iron and manganese to background conditions. Background conditions are best evaluation through future monitoring to address temporal and spatial variations. If iron and manganese associated with ground water at Landfill 4 are established to be within background, there will be nor further requirements for restoration.”

4. Response to comment “43”, which should be WDEQ’s comment 3, not EPA comment 43, states that suggested deletions were preserved, “because they are direct quotes out of the Final RI Report.” The purpose of our reviews is to allow development of an acceptable Record of Decision. The response is non-responsive and unacceptable. However, we agree with the remainder of the response in general, that full information is helpful to the reader.

The problems with these portions of Appendix B, as we already stated, are comments such as “considered most likely” etc. The statement, “The areas of lower oxidizing conditions could represent groundwater impacted from the landfill or...” is as significant as counter hypotheses. This should be emphasized equally with other hypotheses. We do not agree that a particular hypothesis is “considered most likely” at this time.

As we do not know that iron and manganese are occurring at natural background concentrations, they may need to be addressed as COPCs in the HHRA in the future. This should be stated, in order for us to agree that they are not being addressed for the time being.

Response: The FS and monitoring plan (Appendix B) contain sufficient detail and information for FS costing purposes. USAF recognizes that additional data needs to be collected to reduce the uncertainty associated with the concentrations of iron and manganese in groundwater, therefore the monitoring plan will be fully developed during the design phase. The refined and fully developed monitoring plan will outline the additional data to be collected and how the data will be used to assess whether iron and manganese concentrations are background concentrations or not.

5. Sections 7.0 and 8.0, include many references to the conclusion that iron and manganese concentrations are naturally occurring background concentrations. These sections need to state that areas of lower oxidizing conditions could represent groundwater impacted from the landfill as discussed in detail above.

Response: The third paragraph in Section 7 of Appendix B was modified to include the following sentence: *“However, the areas of lower oxidizing conditions could also represent groundwater impacted from the landfill or a natural decrease in Eh along the groundwater flow path.”*

The first paragraph of Section 8 already contains very similar statements, therefore it was not modified.

6. Figure 1., replace “confirm” with “confirm or reject”.

Response: Figure 1 was changed to reflect this comment.

Response to Comments

EPA Comments on

Draft Final Feasibility Study Landfill 4, Zone E, Operable Unit 12

Comments are offered on the revised text below, most of which are readily addressable.

1. **EPA General Comment 2:** Wherever RAO 4 is cited, delete “using the cumulative probability approach”. EPA and WDEQ have agreed there is uncertainty about whether the iron and manganese are or are not background and will need to be monitored and statistically assessed. EPA and WDEQ have not necessarily agreed to use the one method which has indicated these metals are background. While this method is one which may be used, EPA believes the decisions should derive from more than one means of statistical evaluation. Appendix B will require corresponding modification.

Response Evaluation: Still need to rephrase. Existing phrasing is presumptive iron and manganese are background. Either use confirm/deny or use the phrasing from LF7 “Restore ground water to beneficial use, which in this case is restoration of iron and manganese to background conditions. Background conditions are best evaluation through future monitoring to address temporal and spatial variations. If iron and manganese associated with ground water at Landfill 4 are established to be within background, there will be no further requirements for restoration.

Response: The above phrasing from LF7 was used on pages ES-2, 2-1, and B-2, where RAO 4 is cited.

SPECIFIC COMMENTS

2. **EPA Specific Comment 5:** Section 1.3.1, Pages 1-3 and 1-4. This section discusses the lateral and vertical extent of Landfill 4. The first paragraph on page 1-4 is confusing. It states that Missile Drive was constructed “over the landfill wastes.” It also states that as-built drawings indicate that “landfill waste was removed beneath the footprint of the road during construction.” The last sentence of the paragraph states that no intrusive investigation was conducted under Missile Drive and that “buried solid wastes approach the edge of the existing road.” This particular inconsistent description appeared in the Remedial Investigation (RI) report, where the submitted documentation was unclear about wastes being removed beneath Missile Drive. If a definitive statement cannot be made at this time, revise the paragraph to indicate that solid wastes likely exist under the road.

Response Evaluation: Revised text states wastes removed shoulder to shoulder. This is probably true to the depth necessary to construct Missile Drive. It's probably not true to the full depths of the waste, nor does the drawing submitted with the RI specify a depth. Excavation at Landfill 2 revealed waste trenches truncated at the top but apparently continuing for a short distance under Missile Drive. Trenching on the opposite side found no waste, which is approximately consistent with boundaries apparent from air photos. In the case of Landfill 4, the road was constructed

through the middle of the landfill. Existing phrasing makes it seem wastes were completely removed, yet there is likely some remaining. This needs revision.

Response: The text was revised as follows: “As-built drawings from the original road construction indicated that landfill waste was removed “from shoulder to shoulder” of the road, at least to the depth necessary to construct Missile Drive. For the purpose of the FS, it can be reasonably assumed that no waste is under the road, however, it is possible that the waste under the road was not completely removed.”

3. **EPA Specific Comment 10:** Section 2.2.2.1.5 Guidelines To Be Considered (TBC). Wyoming’s Voluntary Remedial Action Program (WVRAP) would also be a TBC.

Response Evaluation: No change to text. What the exclusion of CERCLA sites from the WVRAP does is exclude it as an ARAR (meaning neither applicable nor relevant and appropriate). It does not preclude the use of some of the standards where they are useful, such as where there is no other promulgated standard or risk-based concentration. For example, the concentrations for TPH (GRO and DRO) have been used to establish clean up for the co-mingled petroleum wastes. Include it as a TBC (with the preceeding explanation if USAF wishes to explain the appropriate use at sites addressed under CERCLA).

Response: The text was revised to include the following: “Examples include EPA drinking water health advisories, reference doses, and cancer slope factors (SFs). TBCs for Landfill 4 include EPA Presumptive Remedy guidance and USAF guidance documents as well as Wyoming’s Voluntary Remedial Action Program (WVRAP). Although the exclusion of CERCLA sites from the WVRAP does exclude it as an ARAR, it does not preclude the use of some of the standards where they are useful, such as where there are no other promulgated standard or risk-based concentration.”

4. **EPA Specific Comment 13:** Section 3.0, Development and Screening of Alternatives. All of the alternatives as developed would not allow unrestricted use and unlimited exposure, thus these alternatives as remedies are subject to review not less than every five years (i.e., the 5-Year Review). The FS discussion must recognize the alternatives would be subject to this review. The requirement could be lifted from Alternative 5 in the future if the wastes were excavated from beneath Missile Drive and once metals concentrations in ground water are established as background (or restored through a remedy).

Response Evaluation: The requirement was appropriately addressed. However, the corresponding discussions change location. For Alternatives 3 and 4, it was just before institutional controls. It is in the introductory paragraph for Alternative 5. Use parallel structures.

Response: The sentence “This alternative will be subject to review not less than every five years if any waste was left in place and until metals concentrations in groundwater are established as background or restored through a remedy,” was removed from the Alternative 5 introductory paragraph and moved to the Inspections and Monitoring subsection to make the Alternative 5 discussion parallel Alternatives 3 and 4.

5. **EPA Specific Comment 14:** Section 3.1.2, Alternative 2 - Institutional Controls. The discussion includes Air Force Instructions (AFIs) and the Base General Plan (BGP) as means of implementing institutional controls. Within the context of the discussion, clarify (1) The relationship and the differences between the two (or whether they are interchangeable terms); and (2) if different, which is the document/mechanism the Air Force would use at the Base level to enforce/regulate the controls.

Response Evaluation: While the revision is an improvement, this does not clarify the relationship/differences between AFIs and the BGP. Is the BGP enforceable (by the Air Force) as an AFI? Are permits required administratively or through the enforceable AFI?

Response: The text regarding the BGP and AFIs was removed and replaced with the following: “Alternative 2 consists of physical and/or institutional controls to limit access and future development at Landfill 4.”

6. **EPA Specific Comment 18:** Section 3.1.4, Alternative 4 - Engineered Landfill Cap. Include erosion control (e.g., rip-rap) for the areas within the 100-year flood plain to protect the cap from erosion during flooding. Otherwise, explain in the document why not.

Response Evaluation: Vegetation was used to address erosion. This may or may not be sufficient, but EPA will accept it for now. If it is not sufficient, USAF will need to repair and reinforce in the future. In order to avoid a potential ESD in the future to address this administratively, the USAF may want to add a caveat about the vegetation and adding rip-rap if needed.

Response: The text was modified to the following: “Proper revegetation should be sufficient to protect the cap during a flood event because of its low profile, however if it is not sufficient, rip-rap shall be placed to prevent erosion.”

7. **EPA Specific Comment 22:** Section 4.2.3.4, Page 4-4 Alternative 3, Reduction of Toxicity, Mobility, or Volume through treatment. This section implies areas of unburned waste identified in the RI will be removed if this alternative is implemented in an effort to reduce contaminant toxicity. Identify specific areas to be excavated as part of this alternative. Clarify if a “hot spot” is the same as “unburned waste.”

It states that the RI suggests that the Landfill 4 wastes are non-hazardous; however, the analysis and data presented in Section 1.3.2.2 of this document indicate that the waste is hazardous. Because current analysis indicates that the waste is hazardous, the suggestions in the RI should be considered invalid and deleted from this section, unless information is provided to indicate otherwise.

Response Evaluation: Most changes consistently made. However, in the second sentence, identify the areas are identified on Figure 3-1 rather than referring the reader to the RI report.

Response: The sentence was modified to the following: “These areas are identified on Figure 3-1 as buried solid waste.”

8. **EPA Specific Comment 23:** Sections 4.2.2.7 and 4.2.3.7 (Several EPA comments). These sections provide the cost estimate for implementing Alternative 3. The cost estimate does not appear to account for the excavation, handling, and disposal of hazardous waste at an off-site facility. The section also indicates that a 5 percent discount factor was used to calculate the net present value (NPV). In the text (or by a footnote), explain the 5 percent discount is used based on agreement of the project managers because of the status of F. E. Warren AFB as a non-EPA Federal lead.

Response Evaluation: Responsive in making the change. However, correct the typo from Federal “Land” to Federal “Lead”.

Response: The typo was corrected in both sections 4.2.2.7 and 4.2.3.7.

9. **EPA Specific Comment 40:** Appendix B. The focus of this discussion appears biased in that it appears designed to support only a single method of statistical analysis without actually describing what the issues surrounding the uncertainties in background are.

One of the questions is whether the presumed high TOC is from wastes or naturally-occurring within flood plain sediments. TOC in soil/sediment matrices as well as ground water may be necessary to determine this.

Another is “What is background?”. Water comes from three potentially different geochemical systems (1) underflow in shallow ground water from up gradient through LF4; (2) up welling from beneath LF4 as indicated by vertical gradients; and (3) underflow in the flood plain down stream which may affect results in wells closest to the stream. This appendix discusses the groundwater and surface water monitoring plan for Landfill 4.

How will well and surface water data be correlated to ascertain if LF4 is or is not contributing to Crow Creek?

There is also the potential follow-up question: What if the iron and manganese are not demonstrably background? The monitoring program should also allow the evaluation of potential geochemical attenuation (which appears to be over a relatively short distance based on the short time frame of the RI report).

The monitoring program design must demonstrate how uncertainties will be addressed.

Provide the rationale for the number and location of wells. The rationale should include a discussion of the screening depth and/or target lithology for each well (shallow, intermediate, and deep well), and information concerning the flow paths and gradients that the wells are intended to monitor. Provide a figure illustrating the flow regime which serves as the conceptual basis for this discussion.

Section 6 discusses data to be collected. The third paragraph on page 5-4 indicates that analyses will determine major anions and cations. Provide a table listing all constituents. Include metals and constituents identified which have the potential to be leached from the landfill wastes based on SSL estimates.

Delete “using the cumulative probability approach”. This can be one of the

evaluative methods, but should not be the sole method.

Response Evaluation: Much improved. Well numbers and locations appear generally adequate, except the planned control will not likely allow USAF to evaluate attenuation rates (which are important to evaluating the potential for surface water quality impacts as well as ground water). The area of concern for this is between the approximate locations of MW-60R and MW-283 and surface water sampling point C7. EPA believes this important to address now, rather than conditional to future monitoring results and analysis.

EPA and WDEQ have not agreed to using the cumulative probability approach as the sole method of evaluation, which Section 7 indicates will be the means of evaluation. The conventionally accepted statistical methods must also be used. It may also be necessary to apply these in more ways than the usual up gradient vs down gradient based solely on the water table. If up welling is a significant component, then deep-screened wells may also be 'up gradient' for comparison to shallow-screened wells. There is also an influence which for the lack of a better term is the flood-plain regime, where comparisons along the flow path within the flood plain from up- to down-gradient could be worthwhile or useful in adding to the weight of evidence.

Because the ultimate concentration at a down gradient point is related to both flow and concentration, it will be necessary to assess relative contributions to the system. Vertical permeabilities from deep to shallow and within the flood plain alluviums are needed.

There are many assertions about high naturally occurring TOC within the aquifer materials (solid matrix). However, no data was taken in the RI from the aquifer or the waste materials and both are needed to verify the relative amounts and basis for the assertion/assumption. Few TOC samples have been obtained from the soils on base. Most of those are from the Ogallala Formation or Quaternary Alluvium outside the flood plain. Landfill 4 is sited mainly within flood plain sediments, which may indeed have higher organic carbon contents.

Figure 1, Box for Step 2. Change "One Year" to "Three Years".

Response: The FS and monitoring plan (Appendix B) contain sufficient detail and information for FS costing purposes. USAF recognizes that additional data needs to be collected to reduce the uncertainty associated with the concentrations of iron and manganese in groundwater, therefore the monitoring plan will be fully developed during the design phase. The refined and fully developed monitoring plan will outline the additional data to be collected and the methods to be used to assess whether iron and manganese concentrations are background concentrations or not. This clarification has also been added to the introduction section of Appendix B.

On Figure 1, "One Year" was changed to "Three Years".

Response to Comments

WDEQ Comments on

Draft Feasibility Study Landfill 4, Zone E, Operable Unit 12

Comments are offered on the revised text below, most of which are readily addressable.

1. In particular in Section 2.2, Remedial Action Objectives, and in Appendix B, Groundwater and Surface Water Monitoring Plan, statements are made that presume iron and manganese concentrations are within background concentrations. For example, page b-5, Section 8.0, first paragraph, states that "iron and manganese are believed to occur because iron and manganese are naturally released from the aquifer materials." As a second example, page B-6, second paragraph, states that "additional data will be used to verify that the lower Eh conditions (a reducing environment) are naturally occurring." WDEQ does not agree with the apparent presumption that iron and manganese concentrations are within background concentrations.

Table 3-4 in the RI showed:

- iron in groundwater at 7600 ug/l in MW-060 (WDEQ groundwater standard is 300 ug/l), and,
- manganese in groundwater at 2500 ug/l in MW-060 (WDEQ groundwater standard is 50 ug/l).

These concentrations, substantially above the standards, merit closer scrutiny prior to the determination that iron and manganese concentrations are within background.

As stated in EPA's comments, we have agreed there is uncertainty about background for iron and manganese and that these will need to be monitored and statistically assessed.

Therefore, the second sentence in Remedial Action Objective 4, "The background concentrations defined in the RI using the cumulative probability approach are to be confirmed through future monitoring," should be deleted. This statement is too specific and the concentrations are so much greater than the standards. The first and third sentences alone provide an adequate and comprehensive objective.

Response: RAO 4 was updated in Section 2.2.1 and Appendix B by deleting "using cumulative probability approach", as per EPA General Comment No. 2. RAO 4 now reads: *"Restoration of ground water to beneficial use, which in this case is restoration of iron and manganese to background conditions. The background concentrations defined in the RI are to be confirmed through future monitoring. If iron and manganese concentrations in ground water at Landfill 4 are confirmed to be background through future monitoring, there will be no further*

requirement for restoration.”

2. Appendix B, Sections 7.0 and 8.0 (Decision 1: Are Iron and Manganese Concentrations Confirmed as Background? And Decision 2: Is the Geochemistry Uncertainty Sufficiently Resolved?) need to be re-written to reflect the above, or deleted.

Response: Changes were made to Sections 7.0 and 8.0 of Appendix B, as per the response to EPA Specific Comment No. 40.

3. Appendix B, Section 2.0, Background, second paragraph discusses uncertainties identified in the RI Report. This paragraph states that according to the RI, a “lower oxidizing condition could represent groundwater impacted from the landfill or a natural decrease in Oxidation-Reduction Potential (Eh) along the groundwater flowpath.....Additional data collection in the form of surface water flow and quality monitoring, and monitoring of groundwater elevations and concentrations of contaminants is recommended to.....enable sufficient data to be collected to address these uncertainties.” We agree only with the above statements and suggest deletion of the remainder of this paragraph. The additional text consists of statements such as “considered most likely”, “were assessed to be”, culminating with the statement that “this is uncertain”. These subjective statements and the final qualifier should be deleted.

Response: This text was not deleted in Appendix B because it is a direct quote out of the Final RI Report. By deleting part of this quote, the reader would not be provided with the full amount of information which discusses the conclusions of the RI and uncertainties associated with the concentrations of iron and manganese in groundwater. These statements are backed up with the data and data evaluations presented in the RI report.

4. We agree with the EPA comment that three years of quarterly monitoring is needed to address temporal and spatial variability. Please provide an AFCEE, ASTM, or EPA guidance document that can be referenced for standard monitoring schedules. Also, please provide a rationale if any for variations from the standard schedule.

Response: The groundwater monitoring plan for Alternatives 3 through 5 was changed to 3 years of quarterly monitoring, followed by 27 years of annual sampling, as per the response to EPA General Comment No. 3. A comprehensive monitoring report will be prepared after 5 years of monitoring to assess the comprehensive data set collected since implementation of the remedy and determine if future monitoring is warranted at Landfill 4. These updates to the monitoring plan were made in Sections 3.1, Table 4-2 and Appendix B.

Response to Comments

EPA Comments on

Draft Feasibility Study Landfill 4, Zone E, Operable Unit 12

Comments are offered on the revised text below, most of which are readily addressable.

1. **EPA General Comment 1.** Define nomenclature for the benefit of the public and/or to clarify terms which may be subjective. Examples include: “hot spots,” “putrescible wastes,” and “hazardous wastes.” Sometimes it is not clear if these are different materials, or sometimes considered to be the same material. Identify the locations of the different materials on the drawings in this document.

Response: The term “hot spot” was deleted from the text because results of the RI and risk assessment for Landfill 4 do not show areas that contain significantly greater concentrations of contaminants in the waste and/or greater cumulative risk. The term “putrescible” waste was also deleted from the text. For each waste excavation, a description of why the material was being removed is provided in the text. The locations of the waste excavations are also clarified on the drawings.

2. **EPA General Comment 2.** Wherever RAO 4 is cited, delete “using the cumulative probability approach”. EPA and WDEQ have agreed there is uncertainty about whether the iron and manganese are or are not background and will need to be monitored and statistically assessed. EPA and WDEQ have not necessarily agreed to use the one method which has indicated these metals are background. While this method is one which may be used, EPA believes the decisions should derive from more than one means of statistical evaluation. Appendix B will require corresponding modification.

Response: RAO 4 was updated in the Executive Summary, Section 2.2.1 and Appendix B by deleting “using cumulative probability approach”. RAO 4 now reads: *“Restoration of ground water to beneficial use, which in this case is restoration of iron and manganese to background conditions. The background concentrations defined in the RI are to be confirmed through future monitoring. If iron and manganese concentrations in ground water at Landfill 4 are confirmed to be background through future monitoring, there will be no further requirement for restoration.”*

3. **EPA General Comment 3.** Monitoring. One year of quarterly monitoring is proposed for the alternatives which include monitoring (Alternatives 3 through 5). Use three years quarterly monitoring initially to better address temporal and spatial variability. Most accepted methods of statistical monitoring would rely on a minimum of three years data.

Response: The groundwater monitoring plan for Alternatives 3 through 5 was changed to 3 years of quarterly monitoring, followed by 27 years of annual sampling. A comprehensive monitoring report will be prepared after 5 years of monitoring to assess

the comprehensive data set collected since implementation of the remedy and determine if future monitoring is warranted at Landfill 4. These updates to the monitoring plan were made in Section 3.1, Table 4-2 and Appendix B.

4. **EPA General Comment 4.** Rather than repeat comments, EPA will not comment on the Executive Summary. Changes corresponding to the main text will also need to be made to the Executive Summary.

Response: The corresponding changes have been made to the Executive Summary.

SPECIFIC COMMENTS

5. Section 1.3.1, Pages 1-3 and 1-4. This section discusses the lateral and vertical extent of Landfill 4. The first paragraph on page 1-4 is confusing. It states that Missile Drive was constructed “over the landfill wastes.” It also states that as-built drawings indicate that “landfill waste was removed beneath the footprint of the road during construction.” The last sentence of the paragraph states that no intrusive investigation was conducted under Missile Drive and that “buried solid wastes approach the edge of the existing road.” This particular inconsistent description appeared in the Remedial Investigation (RI) report, where the submitted documentation was unclear about wastes being removed beneath Missile Drive. If a definitive statement cannot be made at this time, revise the paragraph to indicate that solid wastes likely exist under the road.

Response: The as-built drawings for the access road (now Missile Drive) presented in Appendix M of the RI Report indicate that the sanitary waste underlying the footprint were excavated from “shoulder to shoulder” of the road. For the purpose of the FS, it can be reasonably assumed that no waste is under the road. However, if the landfill contents were fully excavated (Alternative 5), additional geotechnical precautions would be warranted to complete excavation of the waste that appears to approach the shoulder of the existing roadway. Section 1.3.1 was revised as follows:

“As-built drawings from the original road construction indicated that landfill waste was removed “from shoulder to shoulder” of the road during construction. For the purpose of the FS, it can be reasonably assumed that no waste is under the road.”

6. Section 1.3.2.2, Pages 1-6 to 1-7. This section discusses waste characterization. Using the 20-to-1 ratio of concentration of a contaminant in the waste to the theoretical concentration of the contaminant in the leachate, the section calculates theoretical concentrations of barium, chromium, mercury, selenium, and lead that may leach out of the waste. All the theoretical concentrations exceed the toxicity characteristic regulatory level (TC). For lead (waste sample location W14), the theoretical concentration exceeds the TC by a factor of 33.

Without an explanation of how the 20-to-1 ratio is actually used, a reader may assume the presented ratios establish a good portion of the wastes in LF4 are indeed characteristically hazardous. The intent of the “20-to-1” rule, also known as the “20 Times Rule” was solely to establish a threshold level based on total content of the analyte for when TCLP testing would be required. Below this threshold, the owner/operator could presume the material would not be characteristically hazardous for a test which intentionally leaches chemicals

from the bulk sample. However, an analytical result above this level does not mean the waste material would be characteristically hazardous. This is because the assumptions in the partition calculations were conservative (such as in more soluble compounds, lower K_d , etc) to derive the lower threshold. It was unrealistic, however, to define an upper level threshold, because of the wide range of solubilities and because a high concentration of relatively non-soluble materials could be present and would nonetheless not “leach” in the TCLP testing. For example, a lead-bearing salt compound is much more “leach able” than lead sulfide or elemental lead under similar near - surface environmental conditions. The primary conclusion which can be drawn from the data is that TCLP testing would be required for wastes which are generated (excavated for disposal outside of LF4).

Comparing theoretical leachate concentrations to ground water concentrations is not valid for the following reasons: (1) TCLP uses three leaching solutions, acid, neutral, and base which are then combined for analysis of the concentration. (2) Part of the concentration in ground water will be background for the discussed metals. (3) Ground water samples would represent a mixture of leachate and background concentrations. Conditions at LF4 are certainly within a narrower pH range and likely closer to neutral. Use SSLs as a better screening tool to estimate whether contaminants can significantly impact ground water.

The last paragraph states that it can be assumed that wastes from Landfill 4 designated for off-site disposal would be non-hazardous and the “...analytical data indicate a slight potential for leachate...” to exceed the TC criteria. Because the theoretical leachate concentrations tabulated in this section exceed the regulatory level by as much as a factor of 33 (for lead, at waste sample location W14), the available information on toxicity characteristics does not justify a blanket assumption all wastes would be non-hazardous if generated from the landfill. Further, based on available data, the term “slight potential” as it relates to leachate generation should be deleted. It clearly indicates TCLP testing would be needed for determining appropriate disposal for wastes generated.

Response: Discussion of detected concentrations in groundwater were deleted from the text as they cannot be definitively used for waste characterization. The following statements were incorporated into Section 1.3.2.2:

First paragraph: *“The 20-to-1 division factor only establishes a threshold level based on total content of the analyte for when TCLP testing would be required, but does not mean that the waste would be characteristically hazardous.”*

Last paragraph: *“Based on the data collected during the RI, additional TCLP analysis would be required to definitively characterize waste designated for off-site disposal in the areas of the waste samples identified above.”*

7. Section 1.3.3.5, Groundwater, Inorganic contaminants. Briefly discuss the uncertainties associated with determining whether iron and manganese are background or not.

Response: A discussion of the uncertainties associated with iron and manganese

concentrations in groundwater was added to Section 1.3.3.5 as follows:

“Although the RI report concluded that the concentrations of iron and manganese in groundwater are likely naturally occurring background concentrations, this is not certain because the high total organic carbon concentrations in groundwater, which influence the iron and manganese concentrations, may either be naturally occurring or a result of the landfill waste. In addition, the source of the shallow groundwater beneath and downgradient of Landfill 4 may be a mix of groundwater from three different flow paths: (1) lateral groundwater flow from upgradient of the landfill; (2) upward groundwater flow from deeper water bearing units beneath the landfill; and (3) lateral groundwater flow in the floodplain adjacent to and parallel to Crow Creek, and flowing from upstream.”

8. Section 1.4, Contaminant Fate and Transport. This deals mainly with contaminant mobility within ground water, overland flow, and wind. Address contaminant mobility from soil/waste materials to ground water.

Response: Additional text was added to discuss the potential for compounds to be leached from waste to groundwater as follows:

“The maximum concentration of contaminants identified in Landfill 4 waste were compared to available Soil Screening Levels (SSLs) to assess the potential for compounds to be leached from waste to groundwater. For contaminants that had an SSL, the maximum concentration of 1,1-dichloroethene, 1,2-dichlorobenzene, 1,2-dichloroethane, 1,4-dichlorobenzene, 2,6-dinitrotoluene, 2-methylphenol, 4,4'-DDD, 4-chloroaniline, antimony, arsenic, barium, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, bis(2-chloroethyl)ether, cadmium, chromium, cyanide, dieldrin, indeno(1,2,3-C,D)pyrene, manganese, mercury, nickel, n-Nitro-di-n-propylamine, pentachlorophenol, selenium, silver, thallium, and zinc exceeded the corresponding SSL (DAF = 1), indicating that they have a potential to be leached from waste to groundwater at a concentration which may impact groundwater quality. As discussed in the RI, of these compounds that exceed the SSLs, only the concentrations of arsenic and manganese consistently exceed groundwater quality standards. However, arsenic is not considered to be contributed to groundwater from Landfill 4 waste, but instead is believed to be naturally occurring. Also, as discussed in Section 1.3.3.5, the concentrations of manganese in groundwater are considered to be background concentrations, although further monitoring is required to confirm this.”

9. Section 1.5.1.2, Groundwater (Page 1-12). Add that the HI is based on the manganese concentrations being presumed background.

Response: The following modifications were made as indicated in the above comment:

“The HI for non-cancer risk for residential exposure to groundwater beneath and downgradient of Landfill 4 below the EPA target HI of 1. This HI is based on the manganese concentrations being presumed background.”

10. Section 2.2.2.1.5 Guidelines To Be Considered (TBC). Wyoming’s Voluntary Remedial Action Program would also be a TBC.

Response: Wyoming's Voluntary Remedial Action Program was not included as Wyoming Statute 35-11-1602(b)(ii) excludes CERCLA sites from this program.

11. Section 2.3, General Response Actions (and Executive Summary). Add that alternatives are being developed to address mainly landfill contents based on the presumption iron and manganese concentrations are naturally-occurring. If monitoring does not verify iron and manganese are naturally-occurring alternative to address ground water will be developed.

Response: The following sentence was added to the end of the first paragraph in Section 2.3 and to the Executive Summary to address this comment:

"The alternatives are being developed to address mainly landfill contents based on the presumption that iron and manganese concentrations in groundwater are naturally-occurring. If monitoring does not verify that iron and manganese are naturally-occurring alternatives to address groundwater will be developed."

12. Section 2.4.2, Page 2-6. This section identifies the process options retained for assembly into alternatives for remediating Landfill 4. The third bullet contains the term "hot-spot excavation and removal." Define the meaning of this term or use a different term. "Hot-spot" is generally defined by greater contaminant concentrations and/or greater cumulative risk. From descriptions later in the document, this may mean particular types of wastes, such as putrescible, or sludge, or unburned solid wastes.

Response: The term "hot-spot excavation and removal" was replaced with "waste excavation and removal".

13. Section 3.0, Development and Screening of Alternatives. All of the alternatives as developed would not allow unrestricted use and unlimited exposure, thus these alternatives as remedies are subject to review not less than every five years (i.e., the 5-Year Review). The FS discussion must recognize the alternatives would be subject to this review. The requirement could be lifted from Alternative 5 in the future if the wastes were excavated from beneath Missile Drive and once metals concentrations in ground water are established as background (or restored through a remedy).

Response: The following statement was added to Alternatives 1 through 4 (Sections 3.1.1, 3.1.2, 3.1.3, and 3.1.4):

"Because this alternative does not allow unrestricted use and unlimited exposure, this alternative would be subject to review not less than every five years."

For Alternative 5 (Section 3.1.5) the following statement was added. The statement also includes the possibility that the 5-year review would be required if any waste was ultimately left in place, due to access limitations, such as excavation along the shoulder of missile drive.

"This alternative will be subject to review not less than every five years if any waste was left in place and until metals concentrations in groundwater are established as background or

restored through a remedy.”

14. Section 3.1.2, Alternative 2 - Institutional Controls. The discussion includes Air Force Instructions (AFIs) and the Base General Plan (BGP) as means of implementing institutional controls. Within the context of the discussion, clarify (1) The relationship and the differences between the two (or whether they are interchangeable terms); and (2) if different, which is the document/mechanism the Air Force would use at the Base level to enforce/regulate the controls.

Response: The first paragraph of Section 3.1.2 was revised as shown below. Minor edits were made to the other portions of this section.

“Alternative 2 consists of institutional controls to limit access and future development at Landfill 4. Base operating procedures as defined by Air Force Instructions (AFIs) for both new construction and repair projects be coordinated with the environmental office. The AFIs also require that installation land use constraints or restrictions be annotated in the Base General Plan. The Base General Plan serves as the primary planning tool for determining future installation activities. The FEW Base General Plan will be amended to include the specific constraints that apply to Landfill 4. Specific institutional controls that apply to Landfill 4 are described below.”

15. Section 3.1.3, Page 3-2. This section describes Alternative 3, localized site improvements. The last paragraph on this page describes excavation and removal activities. Clarify if this is the “hot-spot excavation” referred to in the third bullet of Section 2.4.2. If so, changes corresponding to those in Section 2.4.2 would likely be needed.

Response: The term “hot spot” was deleted from Section 2.4.2. The waste excavation and removal section was revised as following to clarify the purpose of each excavation.

“Waste Excavation and removal activities will include excavating the surficial concrete, demolition debris, and two localized areas identified during the RI. One area of unburned waste is located where methane was detected during a soil gas investigation in 1993. The other area is “stockpiled” waste east of Landfill 4b, which could erode in the future. Three waste samples were collected in these areas during the RI (samples W21, W23, W28, see Figure 3-1). Only sample W21 does not pass the 20-to-1 comparison for TC barium as presented in Section 1.3.2.2. Additional TCLP sampling for barium would be needed for this general area for waste characterization and disposal. For the sake of cost estimation, it is assumed that 95 percent wastes are considered to be non-hazardous and five percent of the wastes waste be managed as hazardous. Non-hazardous wastes could be disposed at the North Weld Landfill near Ault, Colorado, approximately 40 miles south of the Base. Hazardous wastes would need to be disposed at an approved hazardous waste landfill or treated (e.g. stabilized) such that the wastes could be managed at North Weld Landfill.”

16. Section 3.1.3, Waste Consolidation, Page 3-3. The paragraph indicates 30 inches of cover soil will be placed over waste to be consolidated on-site. Describe if there are any required properties of this cover soil (such as permeability, slope) in the section.

Response: Section 3.1.3 was revised as following to generally describe the requirements of the cover soil and the basis for cover thickness.

“In any case, a minimum of 30 inches of cover soil will be placed over such wastes, which would meet the minimum thickness requirement for sanitary landfills in Wyoming and provide adequate separation between the waste material and potential receptors. The cover would be placed, compacted in lifts, and graded to drain, but would not need to meet a specific permeability requirements because the landfill is not being capped with a low permeability cover, as proposed in Alternative 4.”

17. Section 3.1.3, Site Restoration, Page 3-3. The topic of the second paragraph of this discussion is the installation of monitoring wells. This belongs in the following section on Inspections and Monitoring.

Response: The second paragraph was moved to the following section on Inspection and Monitoring.

18. Section 3.1.4, Alternative 4 - Engineered Landfill Cap. Include erosion control (e.g., rip-rap) for the areas within the 100-year flood plain to protect the cap from erosion during flooding. Otherwise, explain in the document why not.

Response: The site restoration discussion in Section 3.1.4 was revised as follows:

“The landfill cap would be re-vegetated with shallow-rooted native grasses to reduce the potential for wind and water erosion. The proposed minimum grade of the landfill cap would be three percent and would eliminate the existing embankment on the south side of landfill 4 along Crow Creek. Proper revegetation would be sufficient to protect the cap during a flood event because of its low profile.”

19. Section 3.1.5, Alternative 5 - Excavation and Disposal. The first paragraph of the subsection on page 3-6 indicates that the solid wastes and intermixed soils would be excavated and transported to a disposal facility that can accept Comprehensive Environmental Response and Liability Act (CERCLA) wastes. Replace “Comprehensive ... (CERCLA)” with “the”. The waste contents are relevant to a facility’s ability to accept wastes more than the program under which cleanup originates. The paragraph also states that “for the purpose of this FS [feasibility study]” the waste is considered to be non-hazardous. The waste characterization data in Section 1.3.2.2, page 1-6, may indicate portions of the waste may be classified as hazardous waste (but would not be determined until TCLP results). For the sake of cost estimation, a percentage of the waste should be assumed hazardous with corresponding changes in Appendix C.

Discuss the probable need to de-water for construction as well as water management (treatment and discharge). Based on partial discussions in the ARARs table, a discharge to Crow Creek is contemplated.

Response: The first paragraph was revised as follows to replace “CERCLA wastes” with “the wastes”, indicate the need for additional waste characterization, and provide a

percentage of “hazardous” waste for cost estimation.

“This alternative would be implemented by excavating, segregating, and temporarily stockpiling the cover soils that overlie the solid wastes. After excavating the cover soil, the solid wastes and intermixed soils would be excavated and transported to a disposal facility that can accept the wastes. For the sake of cost estimation, it is assumed that 95 percent wastes are considered to be non-hazardous and five percent of the waste be managed as hazardous. Additional TCLP analysis for the specific constituents and sample locations identified in Section 1.3.2.2 would be needed for waste characterization and disposal. Non-hazardous wastes could be disposed at the North Weld Landfill near Ault, Colorado, approximately 40 miles south of the Base. Hazardous wastes would need to be disposed at an approved hazardous waste landfill or treated (e.g. stabilized) such that the wastes could be managed at North Weld Landfill.”

Additional discussion of the need to dewater and treat the water prior to discharge was also added to the section, as summarized below.

“Dewatering operations that potentially require discharge to Crow Creek may require treatment of the water before discharge. Groundwater would require treatment for the following compounds (i.e. maximum concentrations of compounds in groundwater which exceed Chapter 1 standards for a Class 2AB stream): benzo(a)pyrene, aluminum, arsenic, chromium, iron, lead, manganese, and mercury.”

20. Section 3.1.5, Alternative 5, Institutional Controls (Page 3-7). The third paragraph of the Excavation and Disposal subsection indicates buried solid waste, if present beneath Missile Drive, would not be excavated as part of this alternative. Institutional controls prohibiting unlimited access to these materials would be needed.

Response: As described in Comment 5, the available information indicates that waste is not present under Missile Drive. However, the following statement was added to this section in the event that excavation along the shoulder of the road becomes problematic for reasons such as road stability concerns or Base use of the road.

“Institutional controls would also be required if any waste was left in place, particularly if excavation along the shoulder of Missile Drive becomes problematic for reasons such as road stability concerns or Base use of the road.”

21. Section 4.2.3, Page 4-3, Alternative 3. The first paragraph indicates that site improvements will consist of surface controls to establish positive drainage patterns across the landfill. Define “positive drainage patterns”. As used, it is vague and could be interpreted to mean a variety of slopes, channels, and other drainage features. Provide additional details, such as features and slopes.

Response Additional information regarding slopes and drainage patterns was incorporated into the 2nd paragraph of Section 4.2.3, as follows:

“Establishing positive drainage across the site will reduce the potential for infiltration into the landfill. The areas that pond storm water would be filled with cover soil and/or regraded

to match the existing cover around the depression(s) and follow the existing surface grades and drainage patterns, which range from one to five percent across the landfill. The established and re-vegetated surface areas will have native deep-rooted grasses, which will serve to stabilize the existing cover and limit the potential for erosion due to wind and water.”

22. Section 4.2.3.4, Page 4-4 Alternative 3, Reduction of Toxicity, Mobility, or Volume through treatment. This section implies areas of unburned waste identified in the RI will be removed if this alternative is implemented in an effort to reduce contaminant toxicity. Identify specific areas to be excavated as part of this alternative. Clarify if a “hot spot” is the same as “unburned waste.”

It states that the RI suggests that the Landfill 4 wastes are non-hazardous; however, the analysis and data presented in Section 1.3.2.2 of this document indicate that the waste is hazardous. Because current analysis indicates that the waste is hazardous, the suggestions in the RI should be considered invalid and deleted from this section, unless information is provided to indicate otherwise.

Response: The assumption that the wastes are non-hazardous was deleted from this section. The term “hot spot” has also been deleted from the document as described in Comment 1.

23. Section 4.2.3.7, Page 4-6, and Appendix C, Alternative 3. These sections provide the cost estimate for implementing Alternative 3. The cost estimate does not appear to account for the excavation, handling, and disposal of hazardous waste at an off-site facility. The section also indicates that a 5 percent discount factor was used to calculate the net present value (NPV). In the text (or by a footnote), explain the 5 percent discount is used based on agreement of the project managers because of the status of F. E. Warren AFB as a non-EPA Federal lead.

Response: As described in comment 15, 5% of the waste designated for disposal is assumed to be hazardous for the sake of cost estimation. The following statement was added to the text regarding the discount factor:

“A 5.0 percent discount factor was used based on the status of F.E. Warren AFB as a non-EPA Federal lead.”

24. Section 4.2.5.7, Page 4-11, and Appendix C, Alternative 5. These sections provide the cost estimate for implementing Alternative 5. It does not account for the waste under Missile Drive.

Response: As described in Comment 5, there is sufficient information to state that waste was removed from underneath Missile Drive. No additional costs are added to Appendix C for road excavation and reconstruction.

25. Table 2-1, Technology Screening and Table 2-2, Process Option Evaluation. Wherever

the term “Deed Restrictions” is used, change this to “Land Use Controls”. Because F. E. Warren AFB was created by an act of Congress, a deed was not created. The equivalent functions of zoning and deeds (land use, easements, covenants, restrictions, etc) are all within the scope of the Base General Plan. Within the corresponding description columns, add a review of digging permits by the base environmental function.

Response: These changes were incorporated into Tables 2-1 and 2-2.

26. Table 4-1, Evaluation Criteria. In the “Description” for Compliance with ARARs, change “waiver is required and how it is justified” to “waiver is justified”.

Response: The sentence has been changed to:

“The assessment against this criterion describes how the alternative will meet the ARARs which are applicable or relevant and appropriate to that alternative, or if a waiver is justified.”

27. Table 4-2, Detailed Analysis of Alternatives. The monitoring duration is presented as five years, which is inconsistent with other descriptions and other landfill closures, which is 30 years.

Response: The groundwater monitoring plan for Alternatives 3 through 5 was changed to 3 years of quarterly monitoring, followed by 27 years of annual sampling (i.e total of 30 years of monitoring). A comprehensive monitoring report will be prepared after 5 years of monitoring to assess the comprehensive data set collected since implementation of the remedy and determine if future monitoring is warranted at Landfill 4. These updates to the monitoring plan were made in Section 3.1, Table 4-2 and Appendix B.

28. Tables 4-3, 4-4, and 4-5, ARARs. Many of the ARARs cited for state-delegated programs (i.e., where the State has primacy) also need to include a cross reference for the corresponding Federal citation. This does not have to mean a doubling of the size of the table. A note in the second column for Citations is generally sufficient to address this.

Response: The corresponding Federal citations were added to Tables 4-3 through 4-6.

29. Tables 4-3, 4-4, and 4-5, ARARs. The Wyoming Solid Waste Rules and Regulations need to be included, broken out, and addressed.

Response: The Wyoming Solid Waste Rules and Regulations were added to Tables 4-3 and 4-4. It was determined that this comment does not apply to Table 4-5.

30. Table 4-3, Analysis of Potential Chemical-Specific ARARs:

Safe Drinking Water Act, Comments. Identify the federal secondary MCLs for iron and manganese, explain secondary MCLs are generally not enforceable as ARARs, and that upgradient concentrations of iron and manganese are greater than the SMCLs.

Wyoming Water Quality Rules and Regulations, Chapter 1. The discussion for at least one of these sections needs to identify which constituents found in ground water (regardless of background or not) approach or exceed the Chapter 1 standards for a Class 2AB stream. This is necessary to evaluate the feasibility of the possible discharge.

Wyoming Water Quality Rules and Regulations (Groundwater). In the comments, provide the iron and manganese standards by concentration. Explain this concentration is the lower of the Class 1 (Drinking Water) and Class 2 (Agricultural) standards. Clarify the concentrations immediately upgradient of LF4 are greater than these standards. Add the maximum detected concentrations for each.

Response: The secondary MCLs for iron and manganese were added to Table 4-3 and a discussion that they are generally not enforceable as ARARs, and that upgradient concentrations of iron and manganese are greater than the SMCLs.

A note was added to Table 4-3 identifying which compounds may require treatment if discharged to Crow Creek during any dewatering operations by listing the groundwater compounds which have maximum concentrations exceeding the Wyoming Water Quality Rules and Regulations, Chapter One standards for a Class 2 AB stream.

The iron and manganese groundwater standards for the Wyoming Water Quality Rules and Regulations (Groundwater) were added to the comments section of Table 4-3. A note was also added to explain that this concentration is the lower of the Class 1 (Drinking Water) and Class 2 (Agricultural) standards and that the concentrations of iron and manganese in groundwater upgradient of LF4 are greater than these standards. A range of the iron and manganese concentrations detected in groundwater is provided.

31. Table 4-4, Analysis of Potential Action-Specific ARARs, Wyoming Hazardous Waste Management Rules and Regulations (WHWMRR). The Comments for Chapter 2 need to be modified. There is a potential for hazardous wastes from generated solid wastes. Alternatives 3 and 4, however, would constitute consolidation within the Area of Contamination (AOC). Alternative 5 would require a testing program with detected hazardous wastes shipped off-site to a permitted facility.

The Comments for Chapter 13 require modifications similar to those for Chapter 2.

Address specifically the portion of the regulations which correspond with RCRA Subtitle D and the closure regulations. This appears to have been omitted. Alternatives

3 and 4 are a form of landfill closure; Alternative 5 would be expected to achieve clean closure except under Missile Drive for landfill contents.

Response: The comments for Chapter 2 and 13 in Table 4-4 were updated as follows:

“Alternatives 1 and 2 – Will not result in excavation of material.

Alternatives 3 and 4 – Hazardous waste could be generated as a result of these alternatives, however, the waste would remain within the Area of Concern and so would not require classification.

Alternative 5 – If hazardous waste is generated by alternative 5, the waste will be characterized for off-site disposal at an appropriate facility”.

Additional information was added to Table 4-4 to address the portion of the regulations which correspond with RCRA Subtitle D and the closure regulations.

32. Table 4-5, Potential Location-Specific ARARs. Wyoming Water Quality Rules and Regulations, Chapter 1. In the Comments, state Crow Creek is a Class 2AB Stream.

Response: Corrected as noted.

33. Table 4-6, Potential Appropriate and Relevant Requirements. Revise the subtitle and corresponding columns to “Relevant and Appropriate”. In the NCP, relevance is a prerequisite to determining appropriateness. For Chapter 2, Section 7(h), use Land Use Controls in lieu of “zoning, deed restrictions”.

Response: Corrected as noted.

34. Figures 1-3 and 1-4. These figures are the site map and the generalized cross-section for Landfill 4, respectively. The site map identifies a cluster of monitoring wells consisting of MW-804, MW-805, and MW-806 and a separate cluster consisting of MW-807, MW-808, MW-809, and MW-810. The cross-section indicates that MW-805 and MW-807 are part of the same cluster. Reconcile the figures/labels to be consistent.

The text indicates that “hot spots” will be excavated. Illustrate the locations of the “hot spots” in Figure 1-3.

Response: Figure 1-3 was revised to indicate the two areas of unburned waste rather than use the term putrescible waste. The excavation of these areas is shown on Figure 3-1 for Alternative 3. Figure 1-4 was updated to correct the labeling of the well clusters.

35. Figure 1-4. A symbol, note, or label is needed for the black squares in a stipple pattern

(presumably representing waste materials) to indicate the meaning.

Response: The “waste” label in the stipple pattern was enlarged to clarify the location of the waste in the cross-section.

36. Figure 1-5. This figure shows the typical landfill profile and identifies the layer beneath the cover soils as “inert solid wastes and soils.” Because the solid wastes are not in fact inert, delete the word “inert” (or add a note to clarify the meaning of the term).

Response: The word “inert” was deleted from the call-out.

37. Figure 3-1. This figure illustrates the plan for Alternative 3. The text indicates that “hot spots” will be excavated. Identify on Figure 3-1 the locations of the currently known “hot spots,” and indicate the criteria to be used if additional potential “hot spots” are found during remediation.

Add generalized cross-sections (similar to Figure 3-3) for Alternative 3 which illustrate minimum slopes and additional relevant subsurface information.

Response: Figure 3-1 was revised to show the two areas of unburned waste identified in the RI that will be removed. As described in Comment 1, the term “hot spot” is not appropriate for these areas. A typical cross section was added to this figure depicting how the depressions will be filled and/or regraded. Note that these areas were identified mainly by field observations because the available topography (2-foot contours) does not pick up these subtle drainage issues. New topographic data will be collected as part of the Work Plan for the remedy.

38. Figures 3-2 and 3-3. Based on Section C on Figure 3-2, there would be a cut slope immediately north west of the guard shelter which exposes waste, rather than covers waste. Modify the alternative to cover or remove (i.e., consolidate) wastes in this area.

Response: The call-out on Figure 3-3 was revised to indicate that any material the would be “cut” (either soil or waste) would be consolidated under the landfill cap.

39. Appendix A. This appendix contains volume calculations. Table 1 refers to Landfill 4a west area and Landfill 4a east area, however, these areas are not correctly identified in the figures in Appendix A. The figures consistently identify the west area as the east area. Revise the table and figures to be consistent.

Identify and indicate the estimated volume of “hot spot” material in the landfill.

The fourth bulletin on page 2 of 3 indicates that a portion of 1,000 cubic yards of

demolition debris may have asbestos-containing material. Provide an estimate of the amount of asbestos-containing material and discuss how this material will be handled and disposed. Because of the potential cost impacts of special handling and disposal requirements, make asbestos disposal a line item (similar to Unexploded Ordnance [UXO]) in the cost estimate (Appendix C).

Response: Figures 1 through 4 were revised to be consistent with the descriptions provided on Table 1. The first two bulletins on page 2 of 3 identify the two areas of unburned trash that would be excavated and disposed as part of Alternative 3. The fourth bulletin indicates that approximately 1,000 CY of demolition debris may be present on the surface at Landfill 4, some of which may contain asbestos. The bulletin was revised as follows:

“Approximately 1,000 cubic yards (based on field observations) of exposed demolition debris (primarily singles, siding, etc.) was observed along the southern boundary of Landfill 4a. Although not quantified, some of the material may be asbestos-containing materials. Further inspection and sampling by a qualified industrial hygienist is needed to determine the type of material present and proper handling and disposal requirements.”

40. Appendix B. The focus of this discussion appears biased in that it appears designed to support only a single method of statistical analysis without actually describing what the issues surrounding the uncertainties in background are.

One of the questions is whether the presumed high TOC is from wastes or naturally-occurring within flood plain sediments. TOC in soil/sediment matrices as well as ground water may be necessary to determine this.

Another is “What is background?”. Water comes from three potentially different geochemical systems (1) underflow in shallow ground water from up gradient through LF4; (2) up welling from beneath LF4 as indicated by vertical gradients; and (3) underflow in the flood plain down stream which may affect results in wells closest to the stream. This appendix discusses the groundwater and surface water monitoring plan for Landfill 4.

How will well and surface water data be correlated to ascertain if LF4 is or is not contributing to Crow Creek?

There is also the potential follow-up question: What if the iron and manganese are not demonstrably background? The monitoring program should also allow the evaluation of potential geochemical attenuation (which appears to be over a relatively short distance based on the short time frame of the RI report).

The monitoring program design must demonstrate how uncertainties will be addressed. Provide the rationale for the number and location of wells. The rationale should include a discussion of the screening depth and/or target lithology for each well (shallow, intermediate, and deep well), and information concerning the flow paths and gradients that the wells are intended to monitor. Provide a figure illustrating the flow regime which serves as the conceptual basis for this discussion.

Section 6 discusses data to be collected. The third paragraph on page 5-4 indicates that analyses will determine major anions and cations. Provide a table listing all constituents. Include metals and constituents identified which have the potential to be leached from the landfill wastes based on SSL estimates.

Delete “using the cumulative probability approach”. This can be one of the evaluative methods, but should not be the sole method.

Response: Section 2.0 of Appendix B provides quotes from the RI report which discuss the conclusions and uncertainties of iron and manganese concentrations in groundwater. An additional paragraph was added to Appendix B to further expand on the uncertainties associated with assessing whether iron and manganese concentrations in groundwater are naturally occurring background concentrations or not: *“Although the RI report concluded that the concentrations of iron and manganese in groundwater are likely naturally occurring background concentrations, this is uncertain because the high total organic carbon concentrations in groundwater may either be naturally occurring or a result of the landfill waste. In addition, the shallow groundwater beneath and downgradient of Landfill 4 may be a mix of groundwater from three different flow paths: (1) lateral groundwater flow from upgradient of the landfill; (2) upward groundwater flow from deeper water bearing units beneath the landfill; and (3) lateral groundwater flow in the floodplain adjacent to and parallel to Crow Creek, and flowing from upstream. Initial investigation (in the RI) of the geochemistry of these three different sources of groundwater indicate that they have similar geochemical characteristics and therefore have similar naturally occurring background concentrations. However, additional data is required to confirm this initial investigation.”*

Further information is provided in Section 9.0 of Appendix B to indicate how it will be assessed whether groundwater from beneath Landfill 4 is or is not contributing compounds to Crow Creek, as follows: *“If any upward trends in concentrations of specific compounds are identified in groundwater, these trends will be compared to trends in surface water concentrations to assess if groundwater is contributing contaminants to Crow Creek. Groundwater contaminants will be considered to be contributing to Crow Creek if the concentrations of compounds which show a repeatable and statistically significant increasing trend in concentrations in groundwater also show a repeatable and statistically significant increasing trend in concentrations in surface water adjacent to Landfill 4 compared to surface water upstream of Landfill 4.”*

Additional information was added to Section 8.0 of Appendix B to indicate that monitoring of potential geochemical attenuation will be undertaken if iron and manganese concentrations are not considered to be background as follows: *“If the weight of evidence indicates that iron and manganese concentrations are not naturally occurring and/or that Landfill 4 is causing a change in Eh resulting in a change in iron and manganese concentrations, an assessment of whether an additional investigation and/or a remedial action is necessary to address iron and manganese concentrations in groundwater will be undertaken. The additional investigation may consist of long-term monitoring to assess whether geochemical attenuation of iron and manganese concentrations in groundwater is occurring.”*

Section 8.0 of Appendix B indicates how the uncertainties associated with iron and manganese concentrations in groundwater will be addressed using the additional data

collected from the existing and new wells. The techniques proposed for evaluating the data to assess uncertainties include: assessing temporal trends of key geochemical parameters and iron and manganese; assessing temporal and spatial consistency of the data; assessing whether the Eh is oxidizing or reducing; assessing whether the TOC concentrations are similar upgradient, beneath Landfill 4 and downgradient of Landfill 4; assessing concentrations of compounds not previously analyzed which are common indicators of landfill impacts (e.g. chloride), using trilinear diagrams to separate natural changes along groundwater flow paths from landfill impacts along a groundwater flow path; assessing vertical groundwater gradients and chemistry from new wells to be installed upgradient and downgradient of the landfill to assess the impacts of deeper groundwater and groundwater in the floodplain on background concentrations; and assessing the interaction between groundwater and surface water in Crow Creek. Details of each of these proposed techniques is provided in Section 8 of Appendix B.

Groundwater flow paths were added to Figure 2 to help show the rationale for the location of the proposed new wells. Table 1 was added to Section 5.0 of Appendix B to provide details of the proposed new well target depths and rationale for the proposed well location. Table 1 is shown below:

Table 1 Proposed Monitoring Well Details

Proposed Well Number	Target Well Depth	Rationale for Well Location
PMW-1	Intermediate	Provide a cluster of wells upgradient of Landfill 4 adjacent to existing well MW-280 to assess the vertical groundwater gradient and chemistry of intermediate and deeper groundwater. This data will be used to assess the influence of upgradient shallow, intermediate and deeper groundwater on the geochemistry and concentrations of iron and manganese.
PMW-2	Deep	
PMW-3	Intermediate	Provide a cluster of wells upgradient of Landfill 4 adjacent to existing well MW-281RR to assess the vertical groundwater gradient and chemistry of intermediate and deeper groundwater. This data will be used to assess the influence of upgradient shallow, intermediate and deeper groundwater on the geochemistry and concentrations of iron and manganese. Two upgradient clusters were chosen to allow evaluation along two different groundwater flow paths.
PMW-4	Deep	
PMW-5	Intermediate	Provide a cluster of wells downgradient of Landfill 4 adjacent to existing well MW-148 to assess the vertical groundwater gradient and chemistry of intermediate and deeper groundwater and the influence of shallow groundwater flowing adjacent to Crow Creek. This data will be used to assess the influence of shallow, intermediate and deeper groundwater on the geochemistry and concentrations of iron and manganese downgradient of Landfill 4. This cluster of wells is located to be on the approximate same flow path as the cluster of wells PMW-1 and PMW-2.
PMW-6	Deep	
PMW-7	Intermediate	Provide a cluster of wells downgradient of Landfill 4 adjacent to existing well MW-283 to assess the vertical groundwater gradient and chemistry of intermediate and deeper groundwater and the influence of shallow groundwater flowing adjacent to Crow Creek. This data will be used to assess the influence of shallow, intermediate and deeper groundwater on the geochemistry and concentrations of iron and manganese downgradient of Landfill 4. This cluster of wells is located to be on the approximate same flow path as the cluster of wells PMW-3/PMW-4 and MW-807/MW-808/MW-810.
PMW-8	Deep	
PMW-9	Intermediate	Provide a cluster of wells downgradient of Landfill 4 adjacent to existing well MW-60R to assess the vertical groundwater gradient and chemistry of intermediate and deeper groundwater and to investigate whether the higher iron and manganese concentrations at this location are related to intermediate or deeper groundwater. This data will be used to assess the influence of shallow, intermediate and deeper groundwater on the geochemistry and concentrations of iron and manganese downgradient of Landfill 4.
PMW-10	Deep	

Table 2 was added to Section 6.0 of Appendix B to provide details of the proposed list of parameters to be analyzed in groundwater and surface samples collected during the monitoring. Table 2 is shown below:

Table 2 Proposed List of Parameters to be Analyzed for Surface Water and Groundwater

Field Parameters (pH, specific conductance, dissolved oxygen, oxidation-reduction potential, temperature)	Major Anions (bicarbonate, chloride,)
Total and Dissolved Metals (aluminum, antimony, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, zinc)	Total Dissolved Solids
Major Cations (calcium, magnesium, potassium)	Total Suspended Solids
Nitrate, Nitrite and Total Kjeldahl nitrogen	Total Organic Carbon
Volatile Organic Compounds	Ammonia
Semi-volatile Organic Compounds	

Reference to using the cumulative probability approach to assess background was changed in Section 7.0 of Appendix B to indicate that it could be one of the approaches used to assess the data collected during monitoring, as follows:

“The data collected during the first three years of monitoring will be added to the RI data and evaluated to assess whether the concentrations of iron and manganese are naturally occurring background concentrations or not. One of the techniques that will be used to make this assessment will be plotting the data on the cumulative probability plots shown on Figures 3 through 6. In conjunction with the results of other evaluation techniques, the concentrations of iron and manganese in groundwater may be considered background if:....”